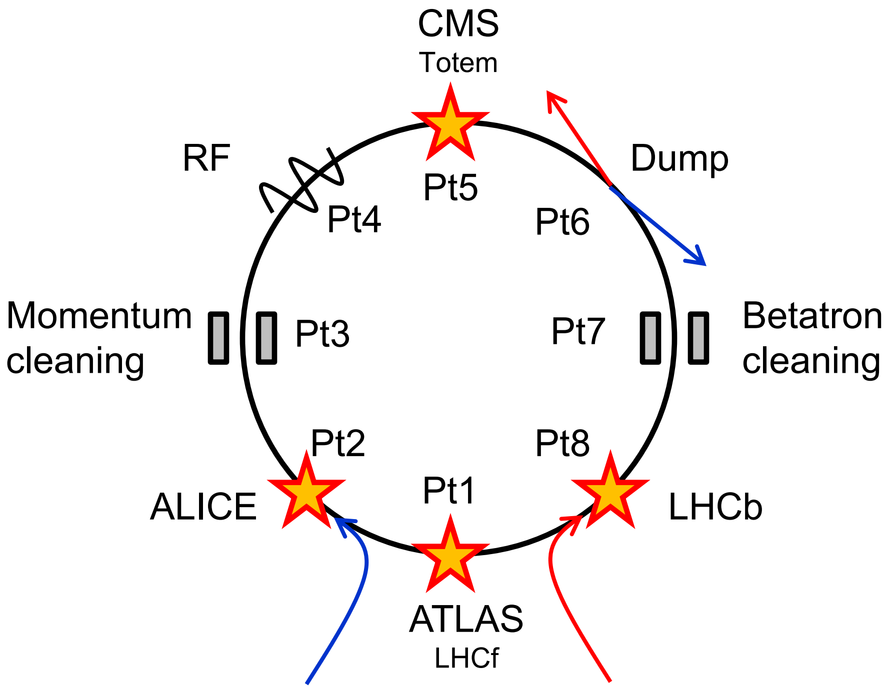
LHC status report

Massi Isnotmax FERRO-LUZZI , LHC (Physics) Programme Coordinator

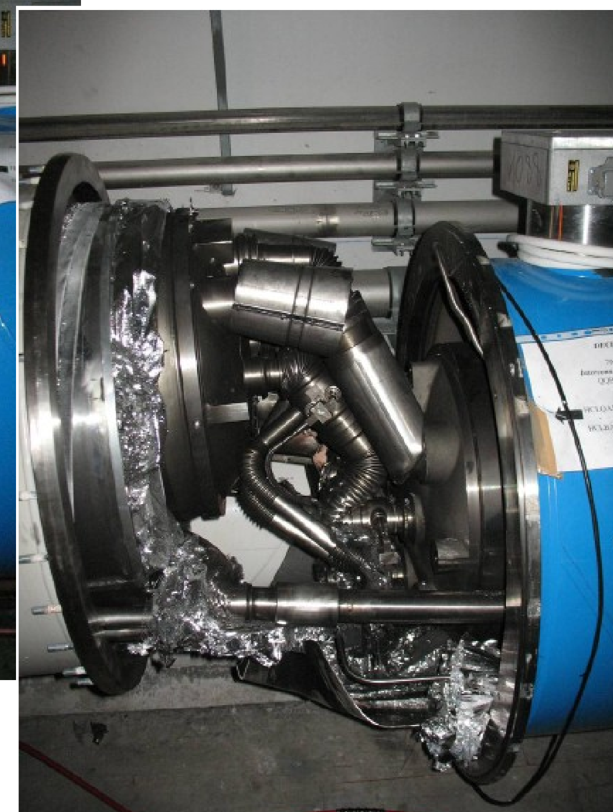
CERN - PH Dept.

- Overview of machine progress
- Recent highlights
  - Squeeze, intensity increase
- Luminosity measurements
  - Van der Meer scans
  - Beam-gas imaging
- Random highlights from the expts
- Prospects and outlook



Rough chronology

2008 s34 incident



Rough chronology

Oct 2008 – Oct 2009: recovered from s34 incident

20 Nov 2009: Resuming (circulating) beam commissioning

6 Dec 2009: First physics collisions at 450 GeV/beam

13-14 Dec 2009: Ramps and collisions to 1.18 TeV/beam

Mid Dec 2009 – End Feb 2010 --- Technical stop

27 Feb 2010: Started LHC (first beams 2010),cmg

20 Mar 2010: First ramps to 3.5 TeV

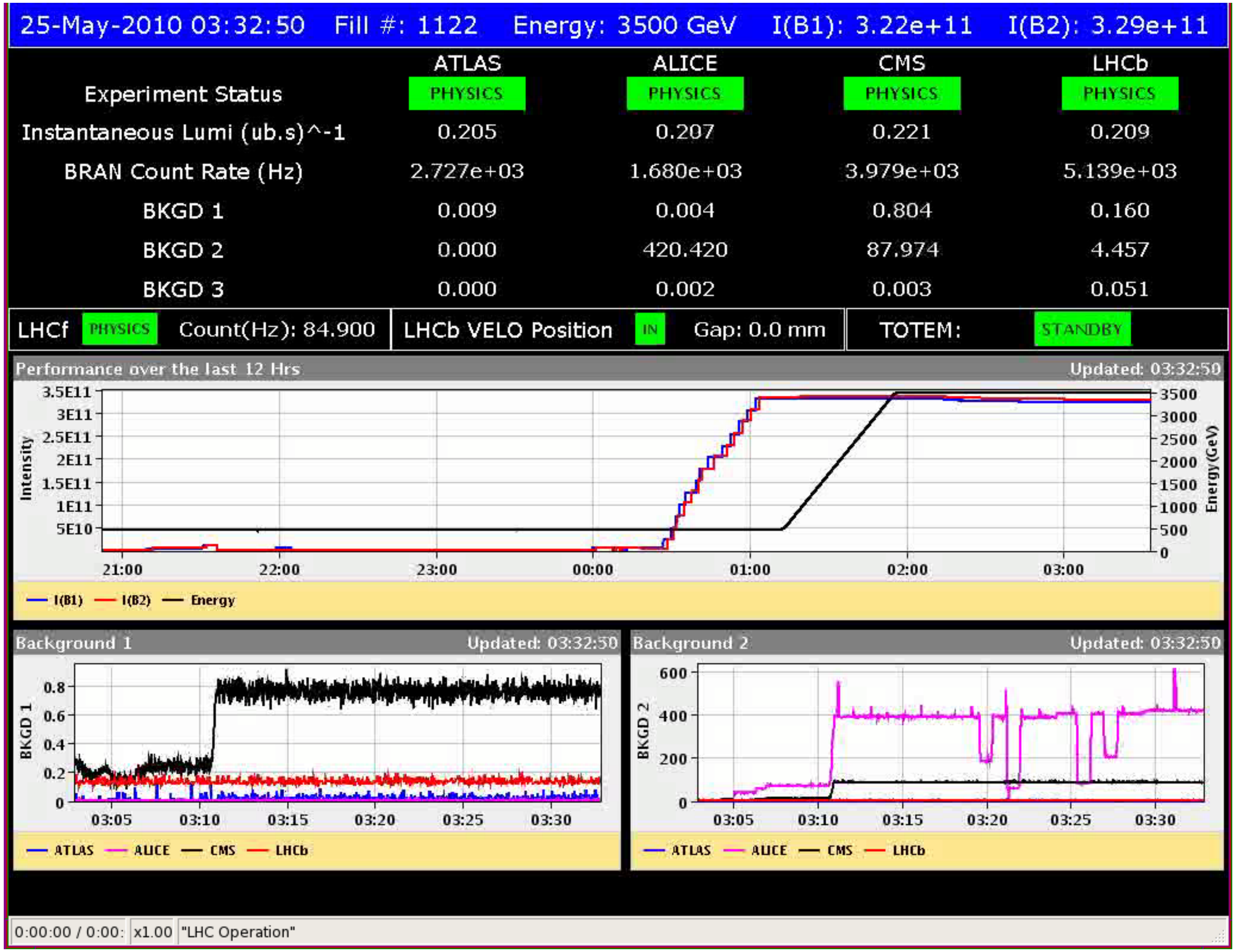
30 Mar 2010: First physics collisions at 3.5TeV/beam

- Started sharing time between physics and beam cmg
- 17 fills with physics ("stable beams")

23 Apr 2010: First run with squeezed optics (beta* = 2m)

- Also, first van der Meer scans
- Started increasing beam intensity…
- Another 17 fills with physics

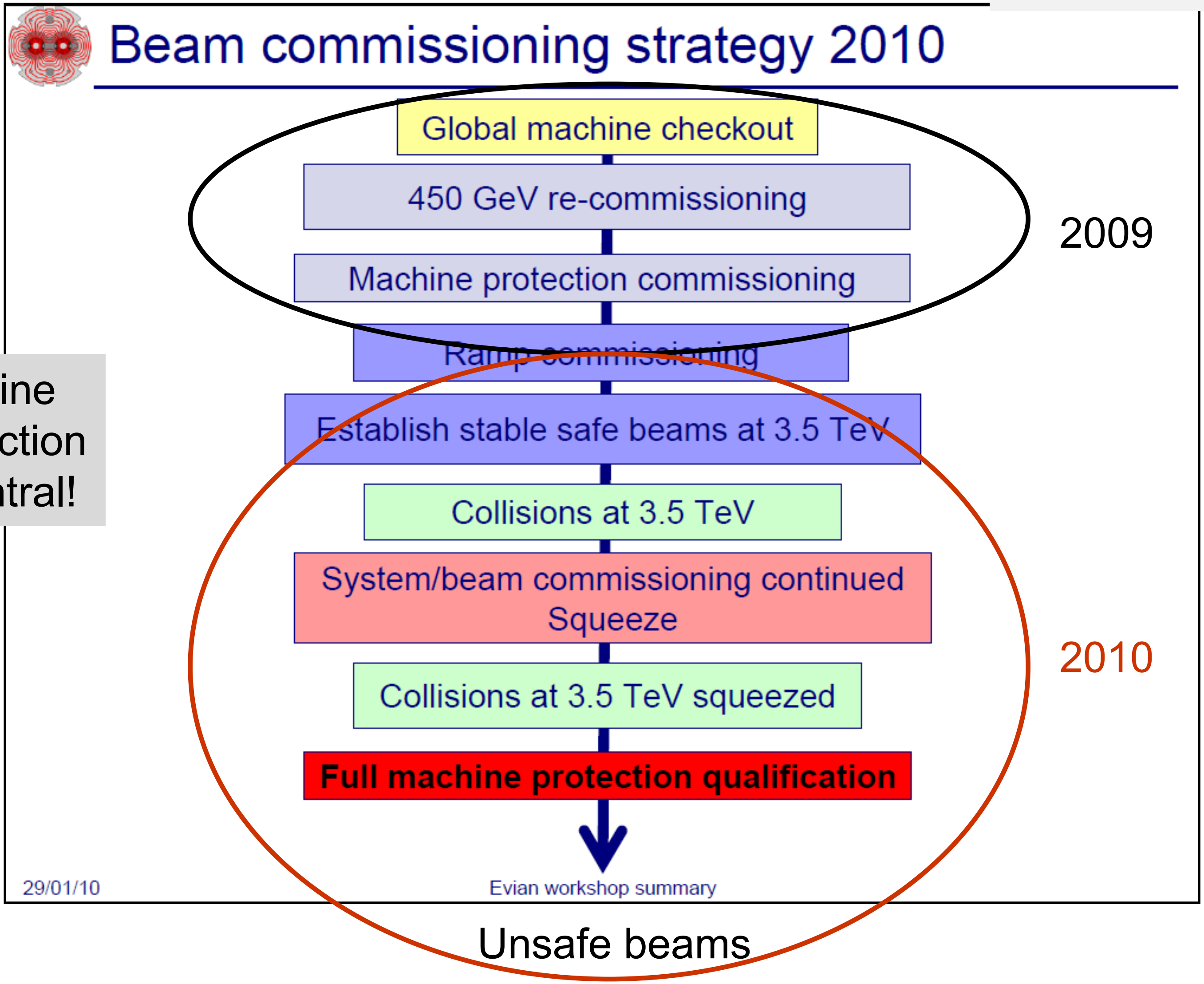
Rough chronology



Now (3 Jun): 13 bch/beam x 2.5e10 p/bch at 3.5 TeV/beam, at β*=2m at all four IP's → 2e29 Hz/cm^2

Beam commissioning

Mike Lamont



Machine Protection is central!

All this done by our machine colleagues in ~3 months.

Outstanding preparation work!

Hardware, controls and software!

Physics data so far

2009

- 900 GeV stable beams ~44h ~10 ub^{-1} (~450 k inelastics) "per IP"
- 2.36 TeV no stable beams ~10% int. lumi of 900 GeV

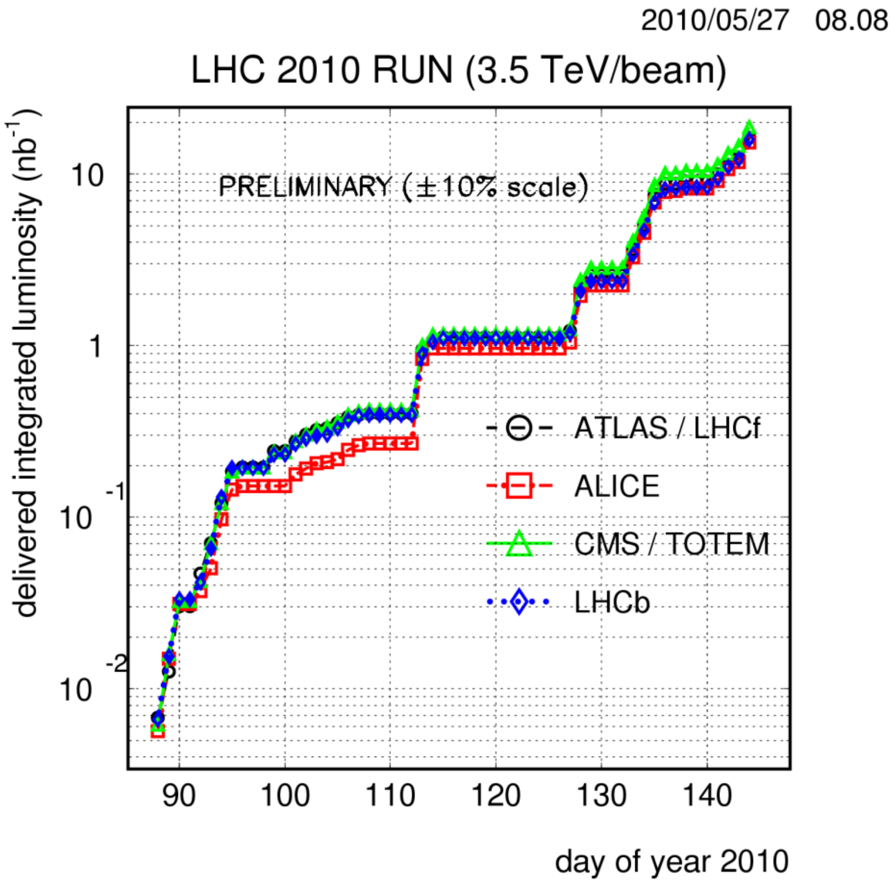
2010

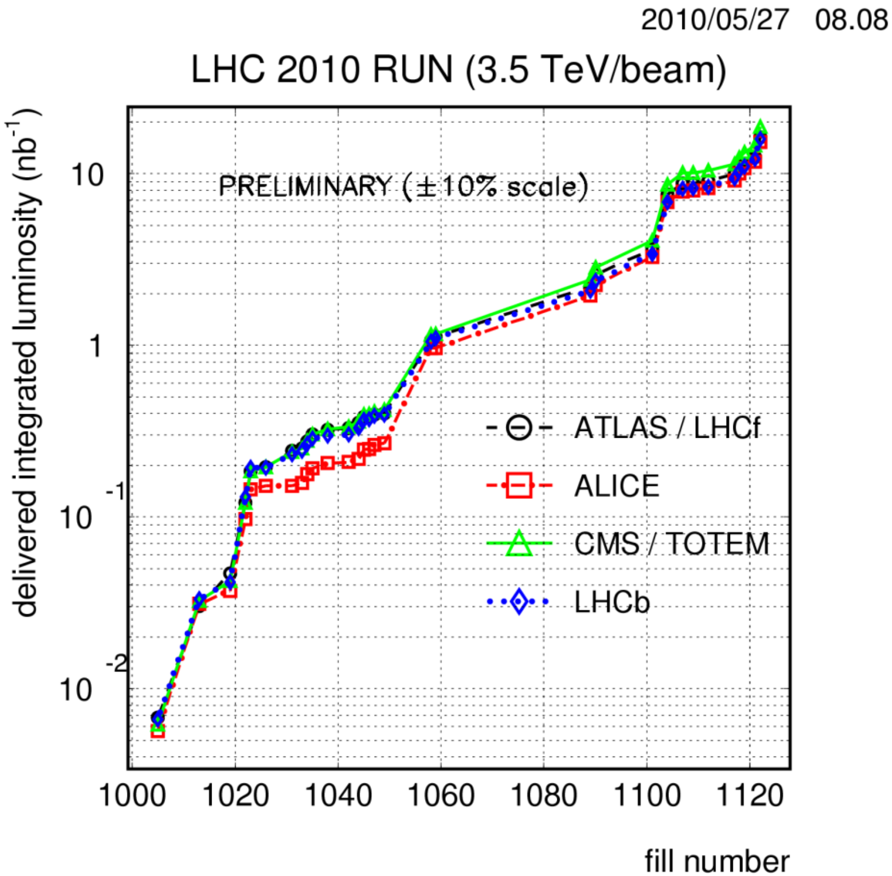
Chapter 1e27	7 TeV, not squeezed, ~1e10 p/bch, 2 bunches
~0.4 nb^{-1}	~98h, 17 fills, 1005 - 1049
Chapter 1e28	7 TeV, squeezed, ~2e10 p/bch, 2-7 bunches
~12 nb^{-1}	~123h, 12 fills, 1058 - 1119
Chapter 1e29	7 TeV, squeezed, ~2e10 p/bch, 13 bunches
~ 4 nb^{-1}	~12h, 2 fills, 1121 - 1122
900 GeV	high intensity, 1e11 p/bch
~350 ub^{-1}	~15h, 2 fills, 1068 and 1069 (and 1128)

Integrated lumi (delivered, in STABLE BEAMS)

(modulo some possible luminometers down time...)

As of 27/may





Plots at http://cern.ch/lpc

Integrated lumi (delivered, in STABLE BEAMS)

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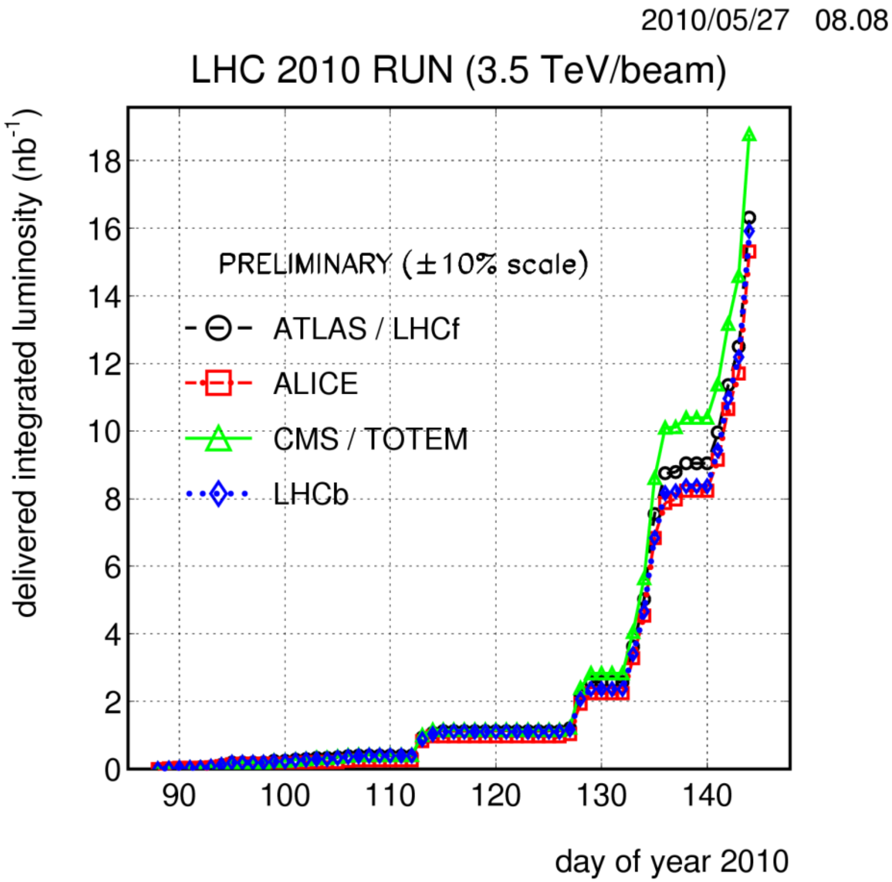
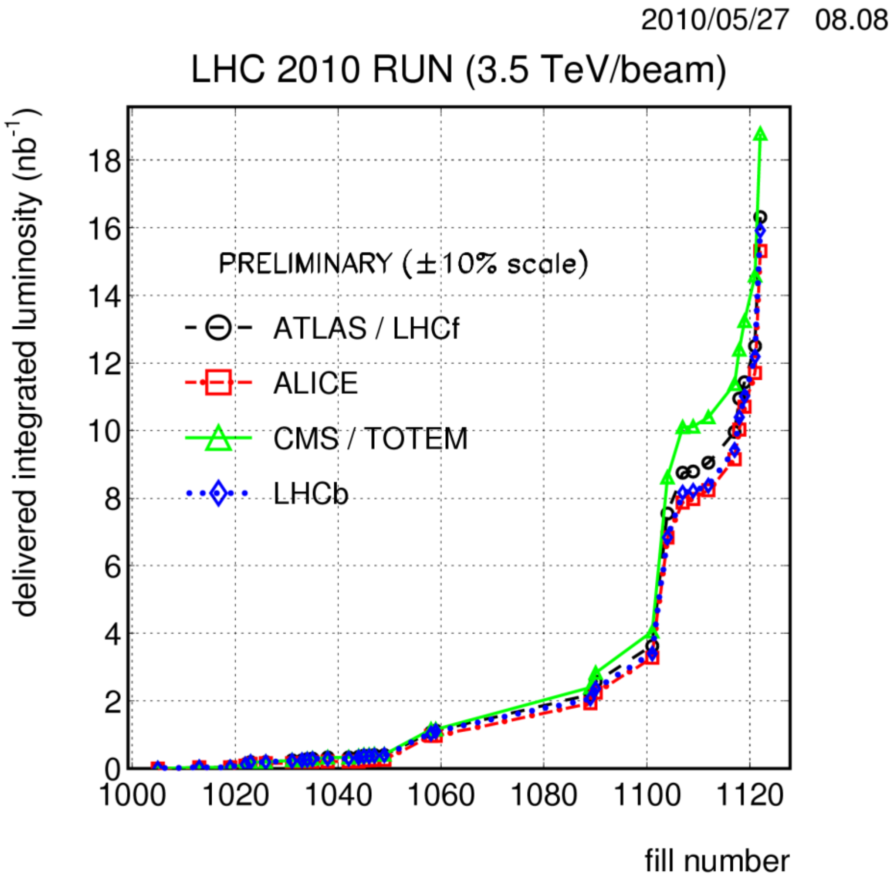




Plots at cern.ch/lpc

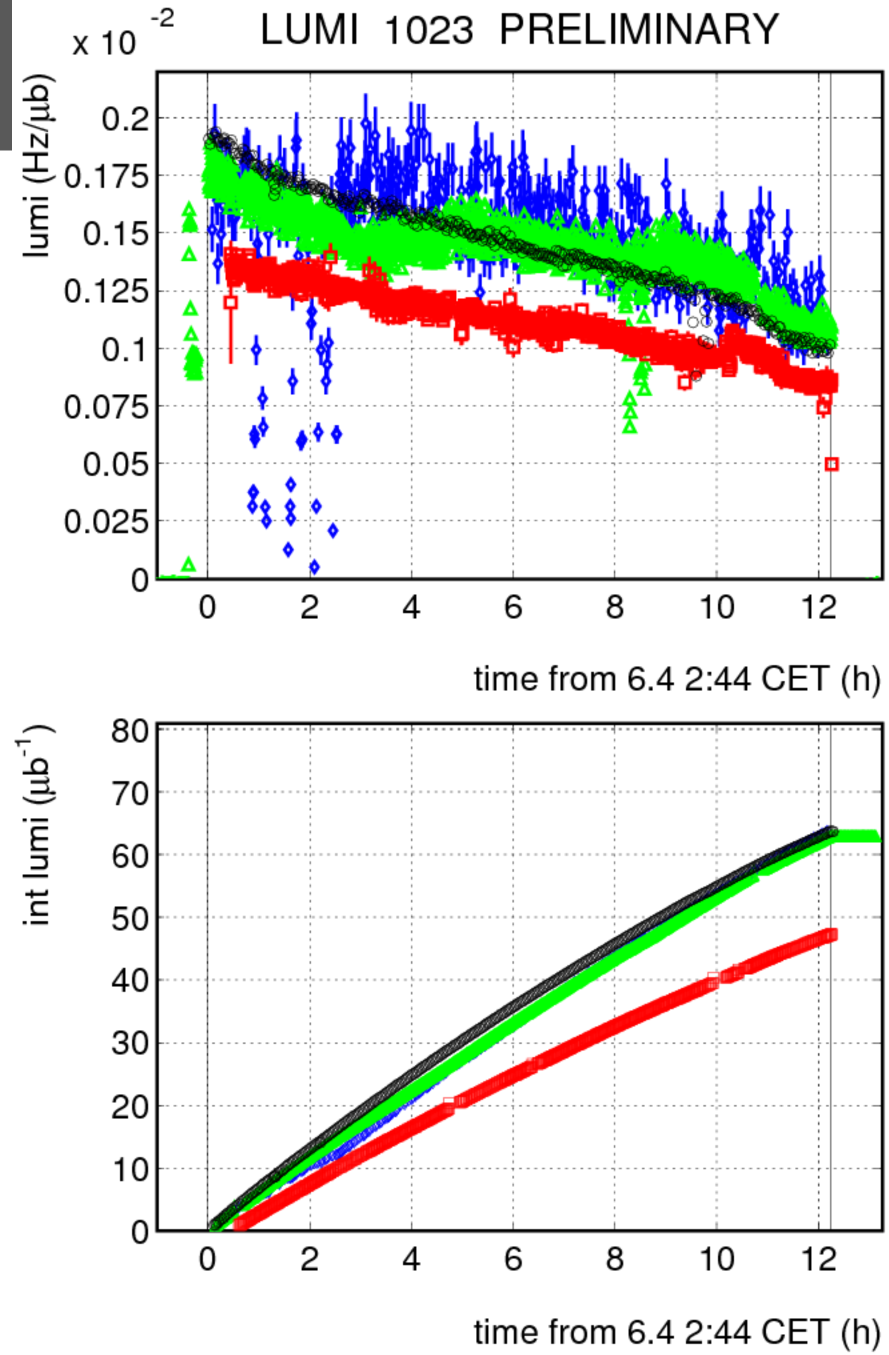
Chapter 1e27

1022: record fill of Chapter 1e27

- 2x2, 1 coll. pair, ~1.1e10 p/bch
- β* = 11-10-11-10 m
- long lumi lifetimes
  - Up to ~50h
- 20 hours stable beams
- ~80/ub

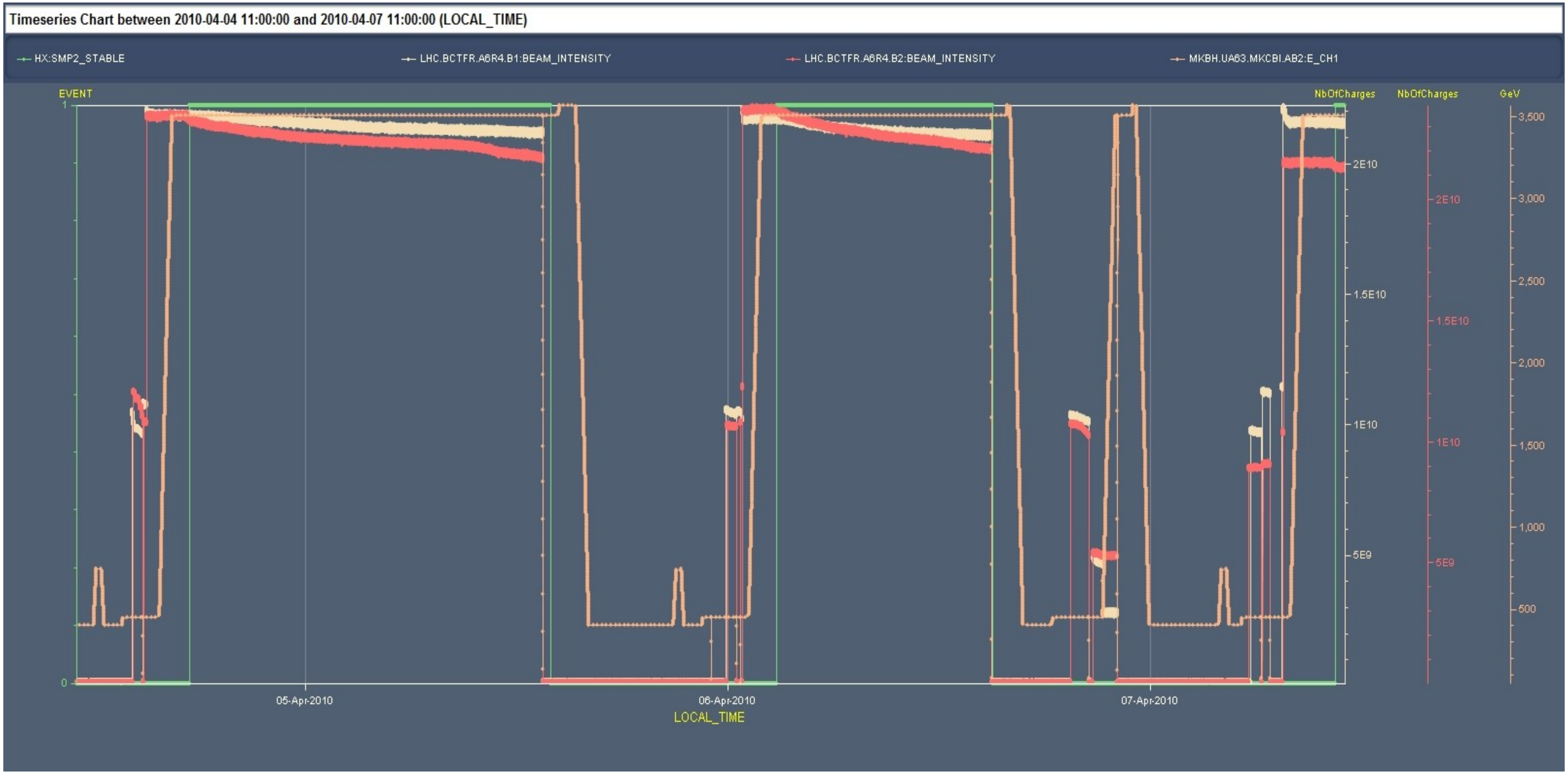
- NB: still some factor 0.9 – 1.1 normalisation correction possible for luminosity scale (work in progress)

Followed by a second nice fill 1023



A good period

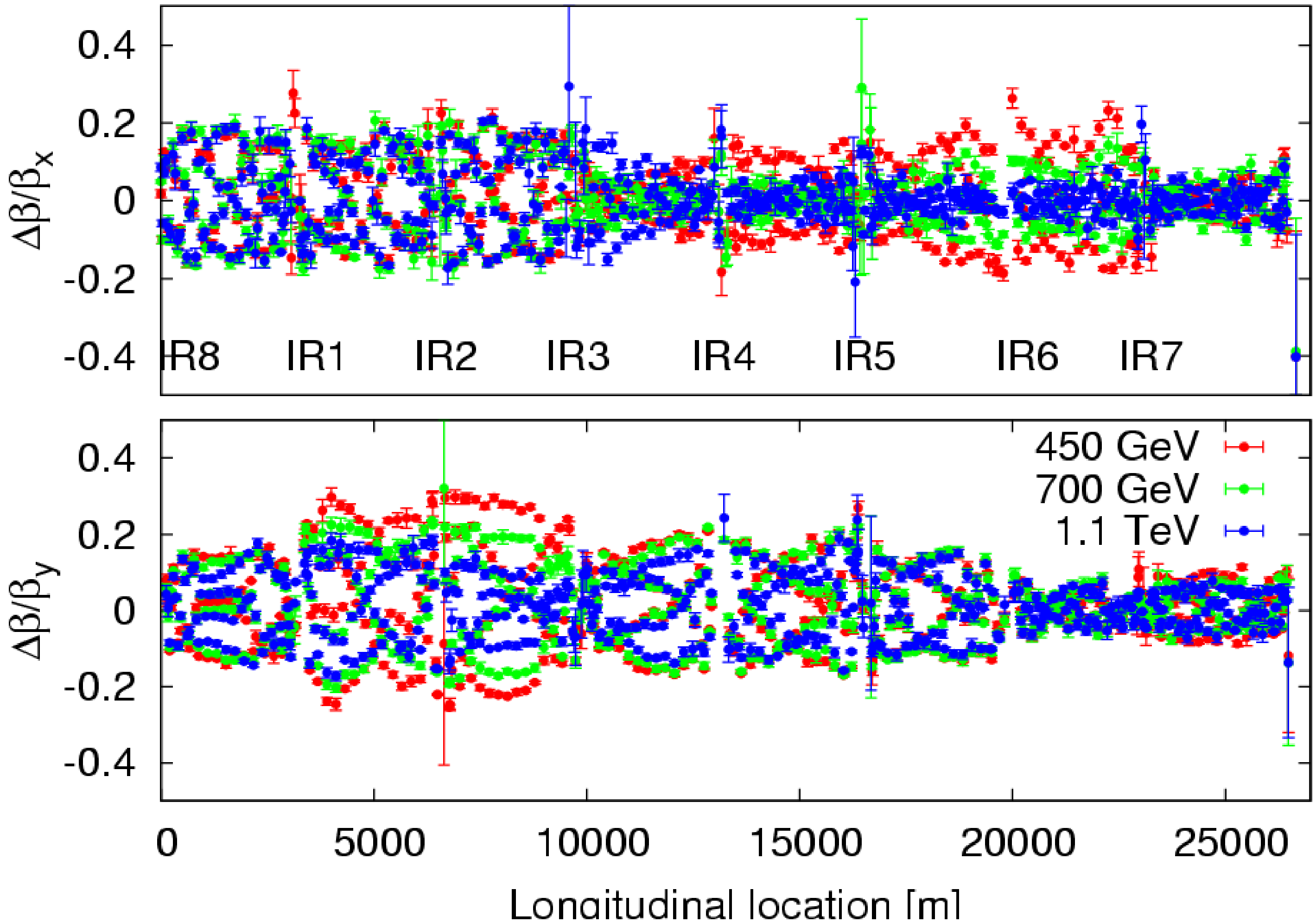
fill 1022 fill 1023



A somewhat less good period

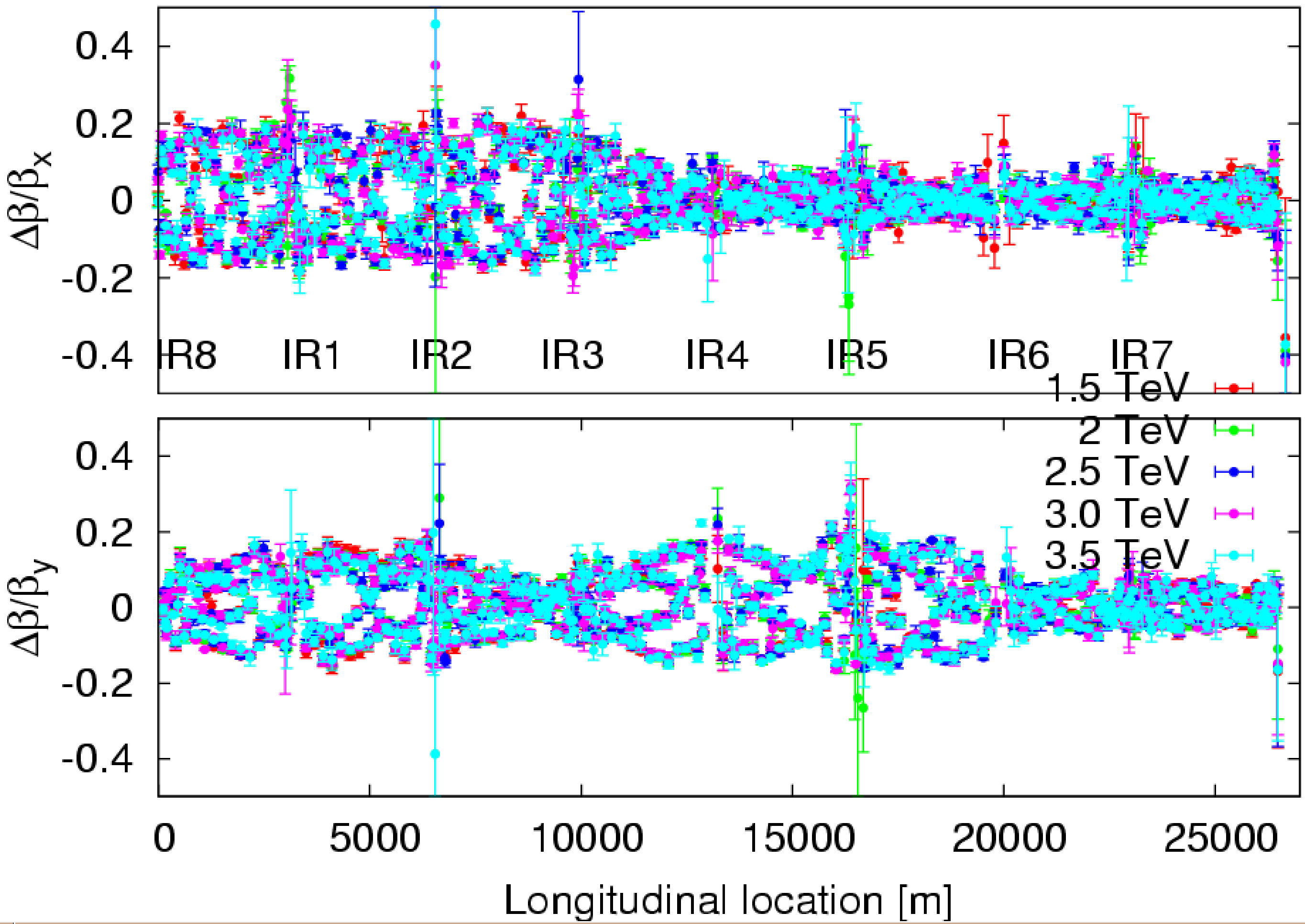
Optics : 450 to 1.1 TeV

- A stable and well measured optics is important for aperture, and can significantly affect the time required to setup (e.g. collimators).



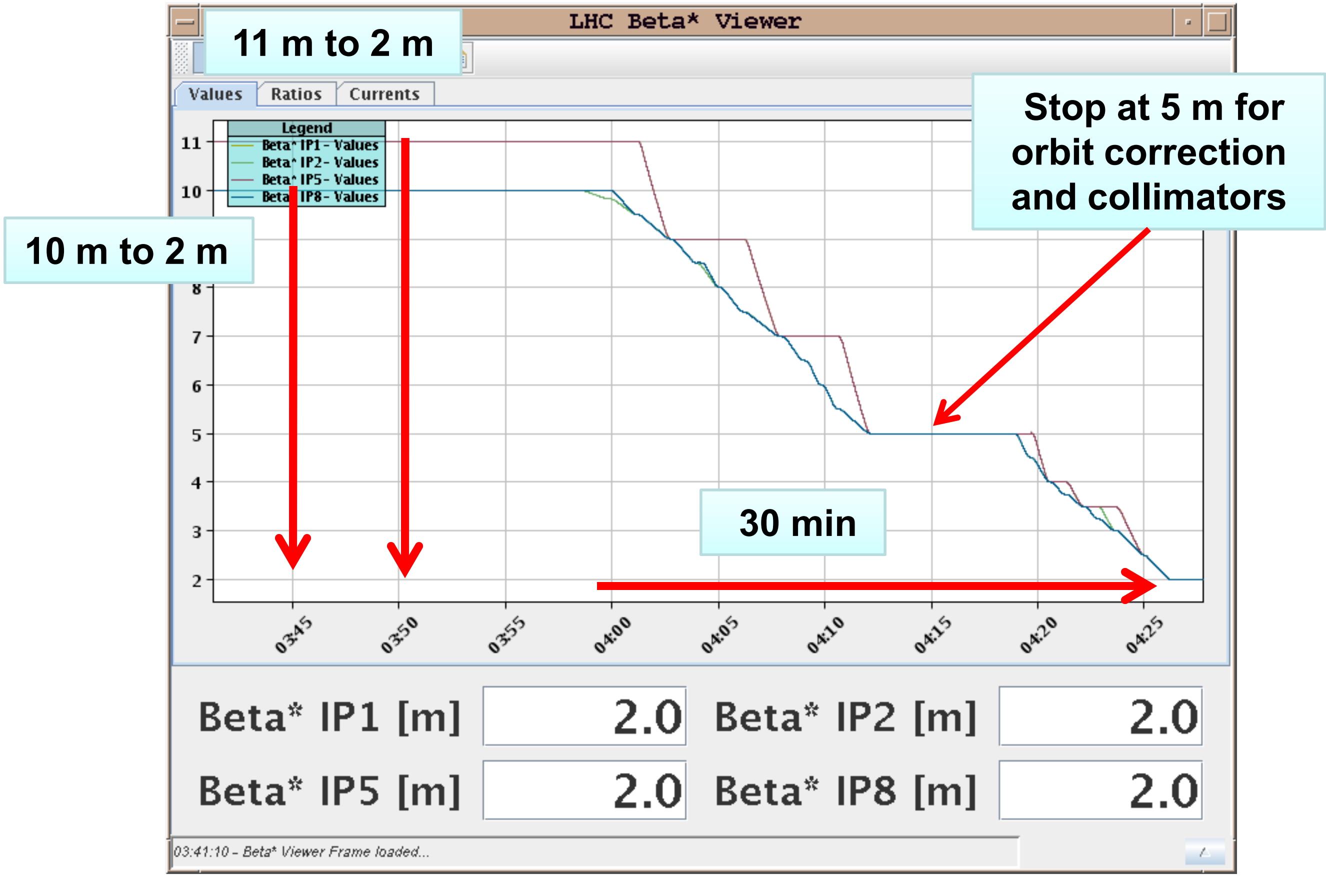
Optics stable from 1.5 to 3.5 TeV

- Impressive stability (and reproducibility) of the optics, thanks to remarkable work on magnet transfer functions by the magnet groups.



Squeeze

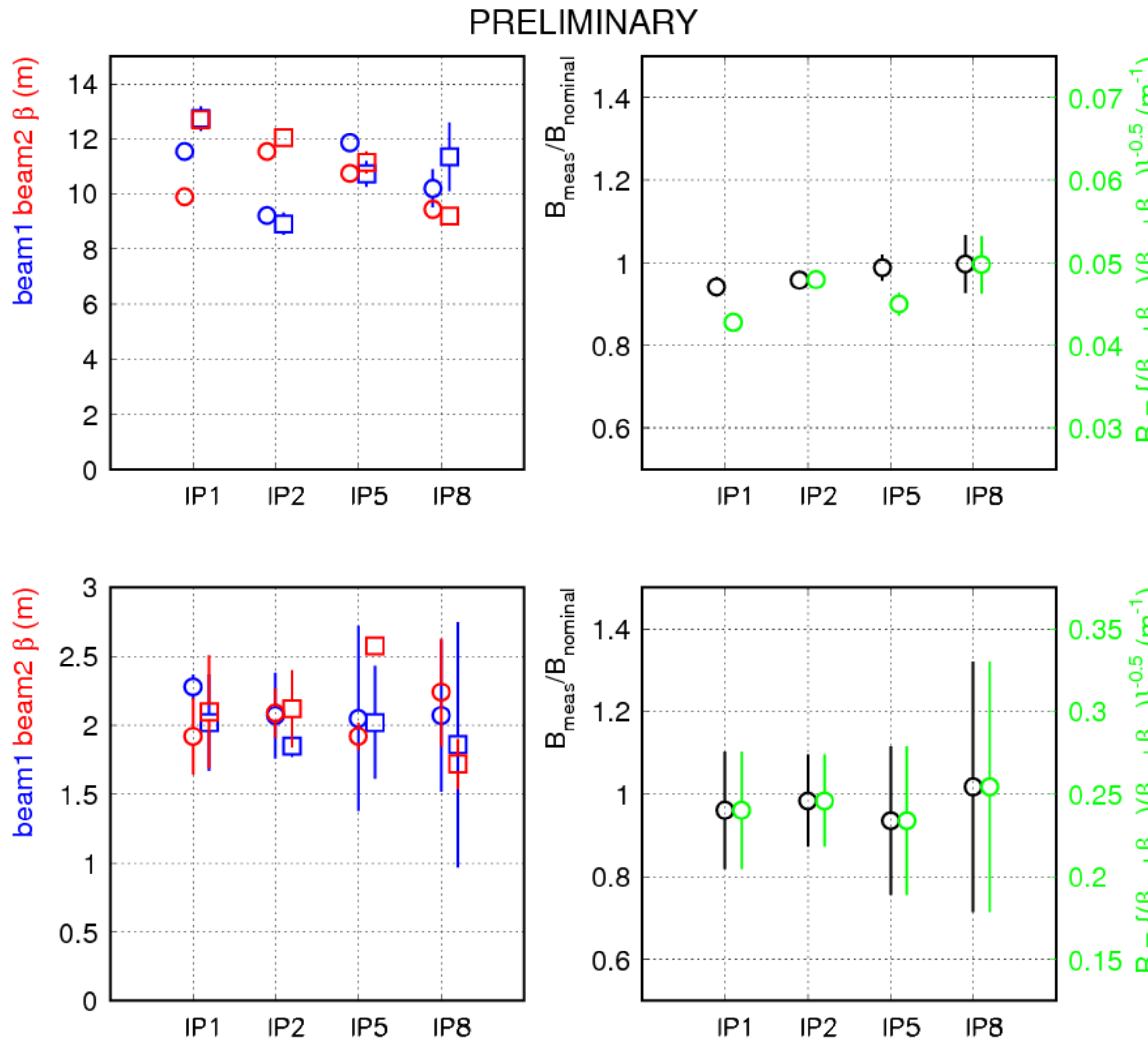
- Since a few weeks, routinely squeeze β^* at the IPs all in parallel to 2m.
- One intermediate stop for orbit correction & final collimator (tertiary collimators near IRs) adjustment.



Measured β* values (3.5 TeV) unsqueezed and squeezed

- Beta* are as expected

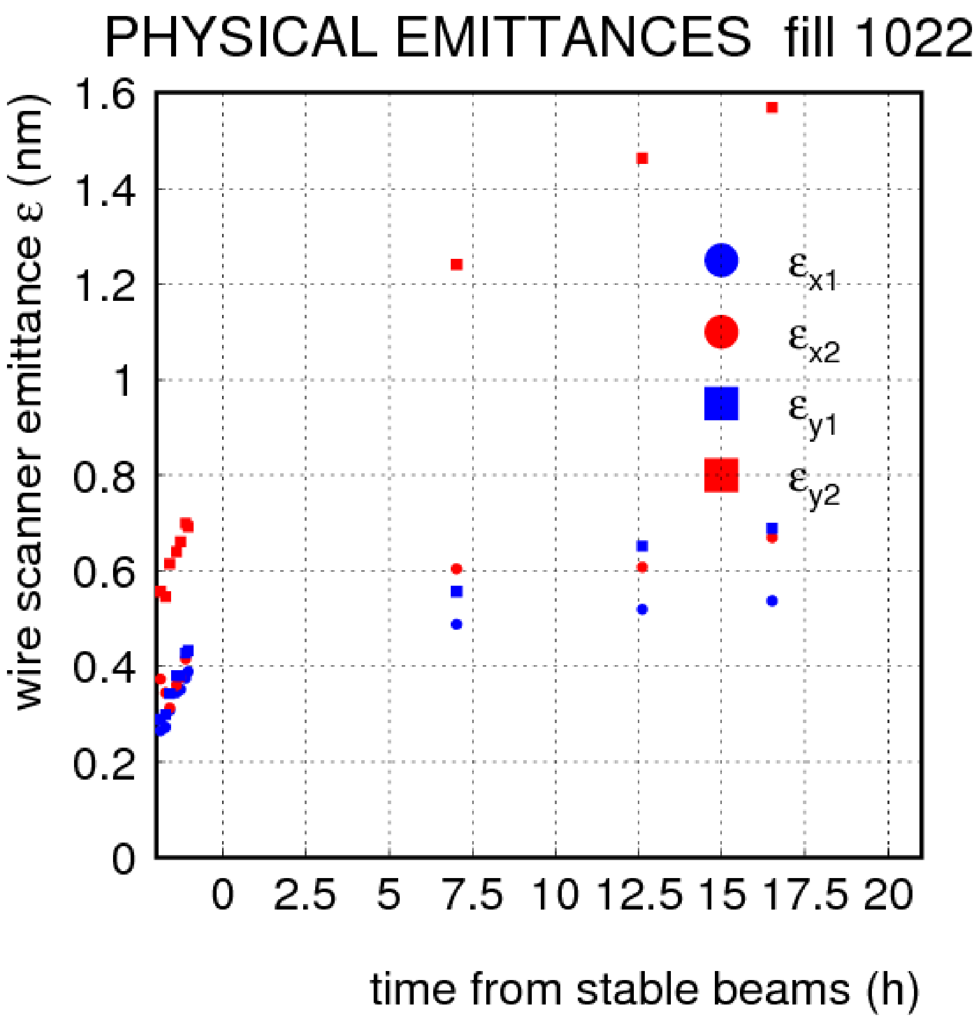
Left plots:
Circles: β_x^*
Squares: β_y^*



Measured transverse emittances

- Wire scanner data
- Gauss sigma transformed to emittance by applying local beta function factor

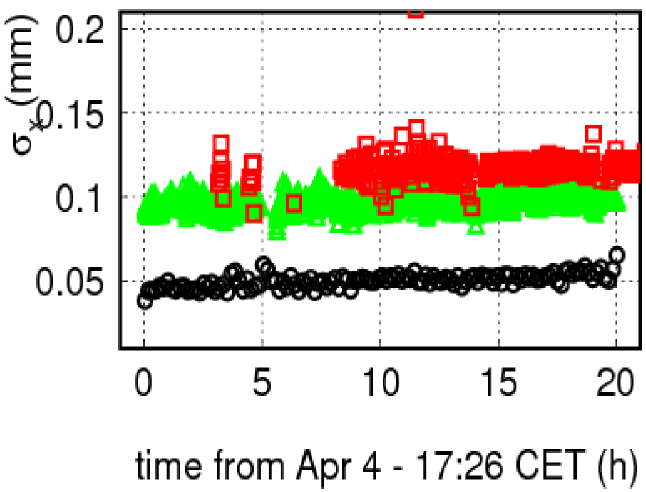
- Sync light monitor also working (yet to be calibrated, as function of beam energy)

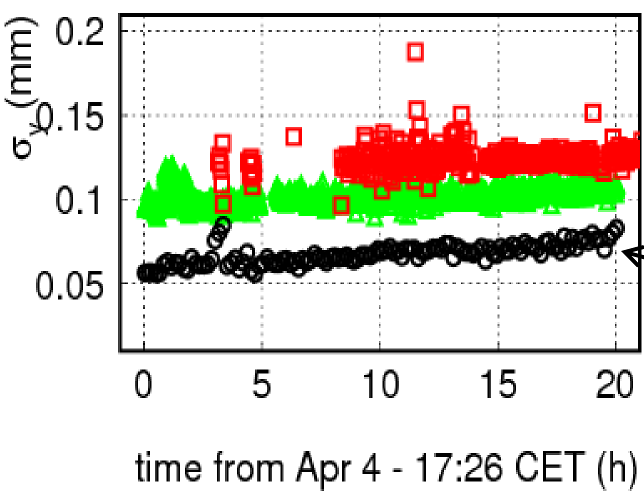


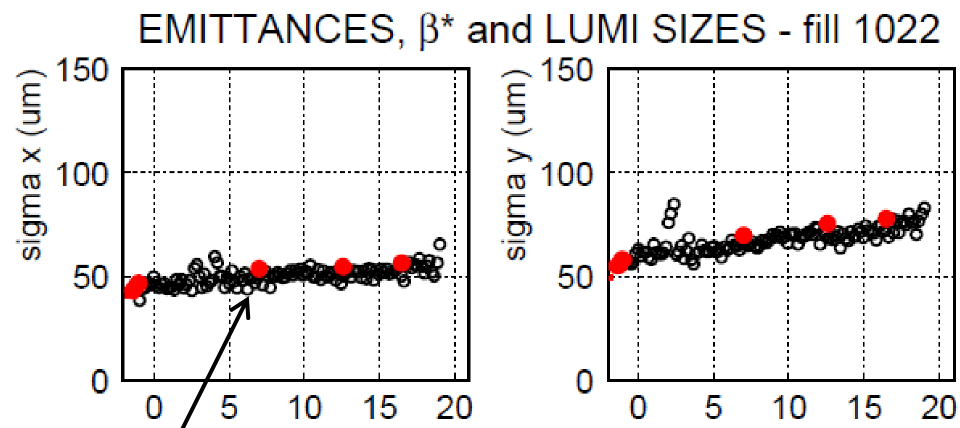
Transverse growth, fill 1022, early analysis

Lumi region PRELIMINARY

From the experiments





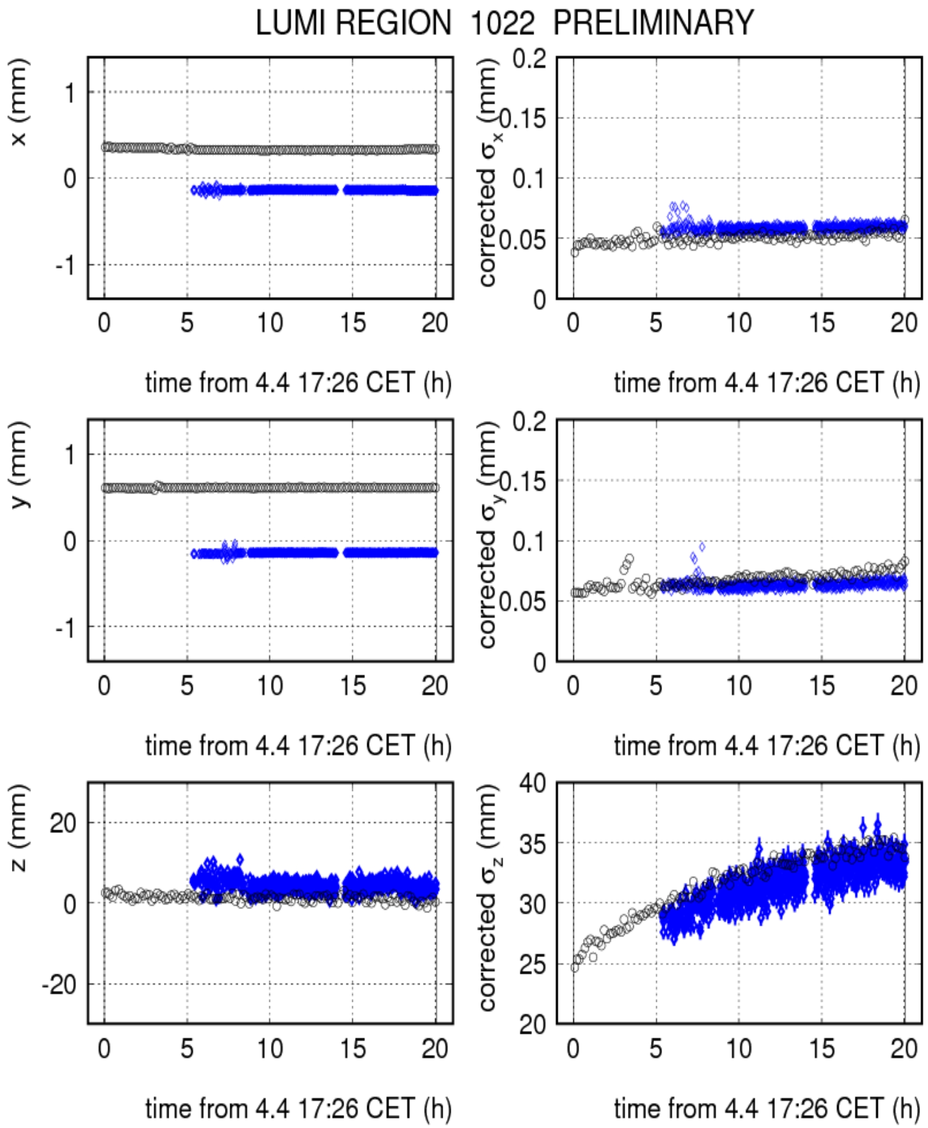


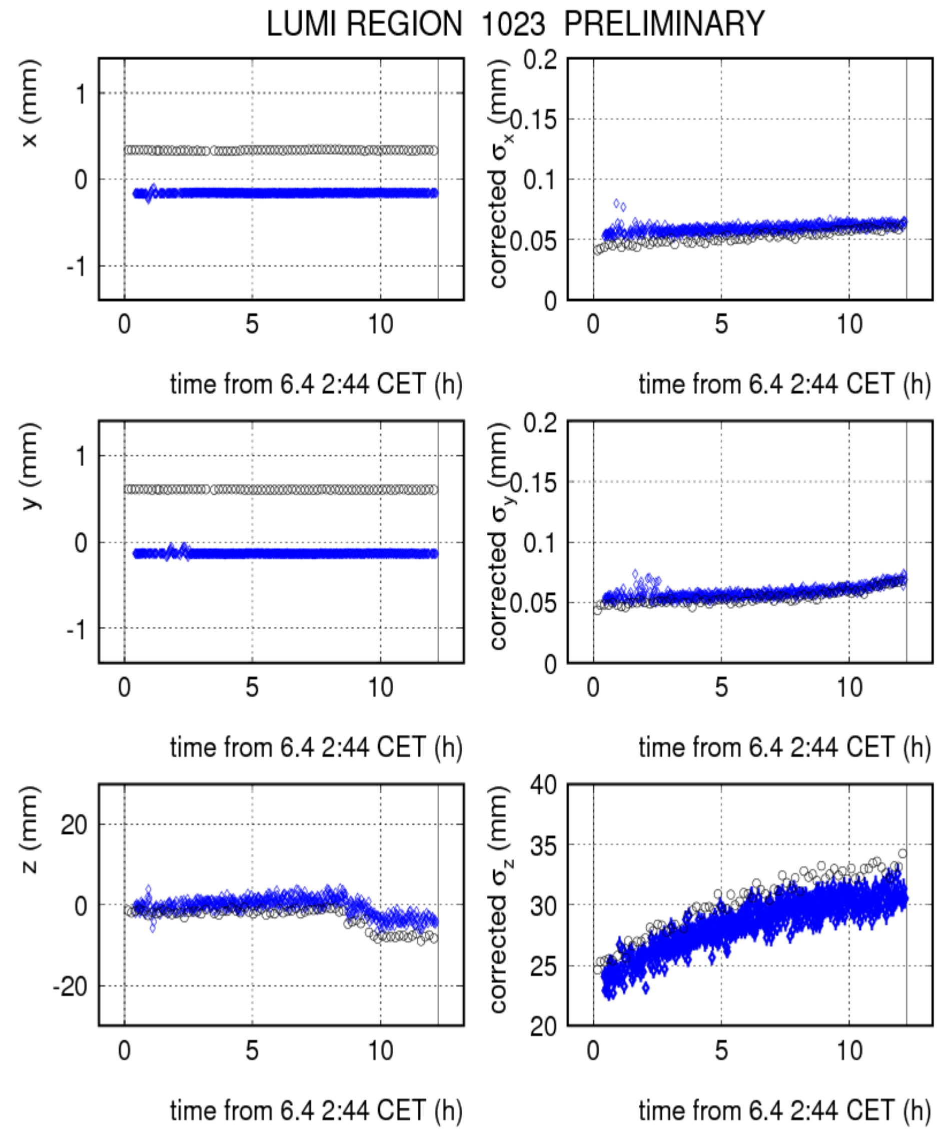
● Reconstructed from β* and emittances

Emittance growth clearly visible
And currently drives the luminosity life time
(which however is very good, typically > ~10 h)

○ vtx resolution unfolded (others not)

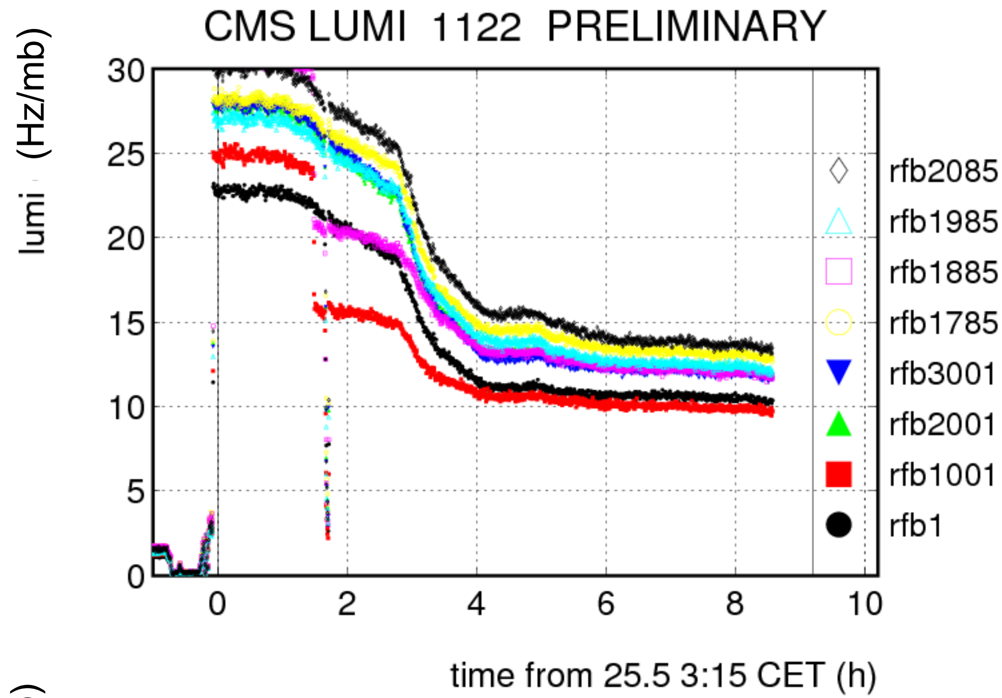
Beam spot parameters (luminous region)

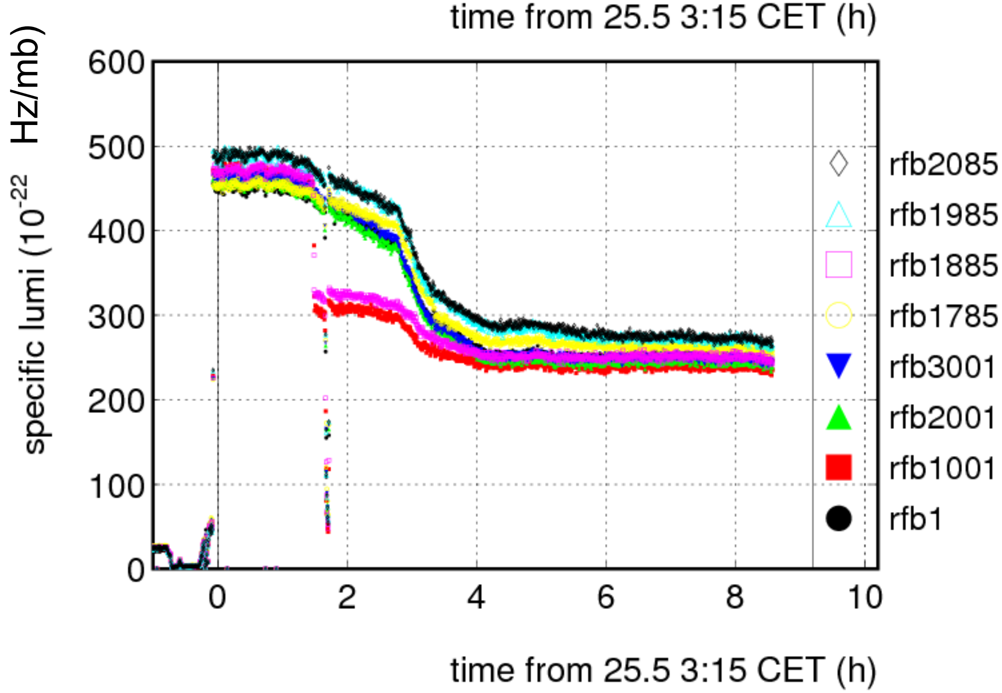




Interesting effects…

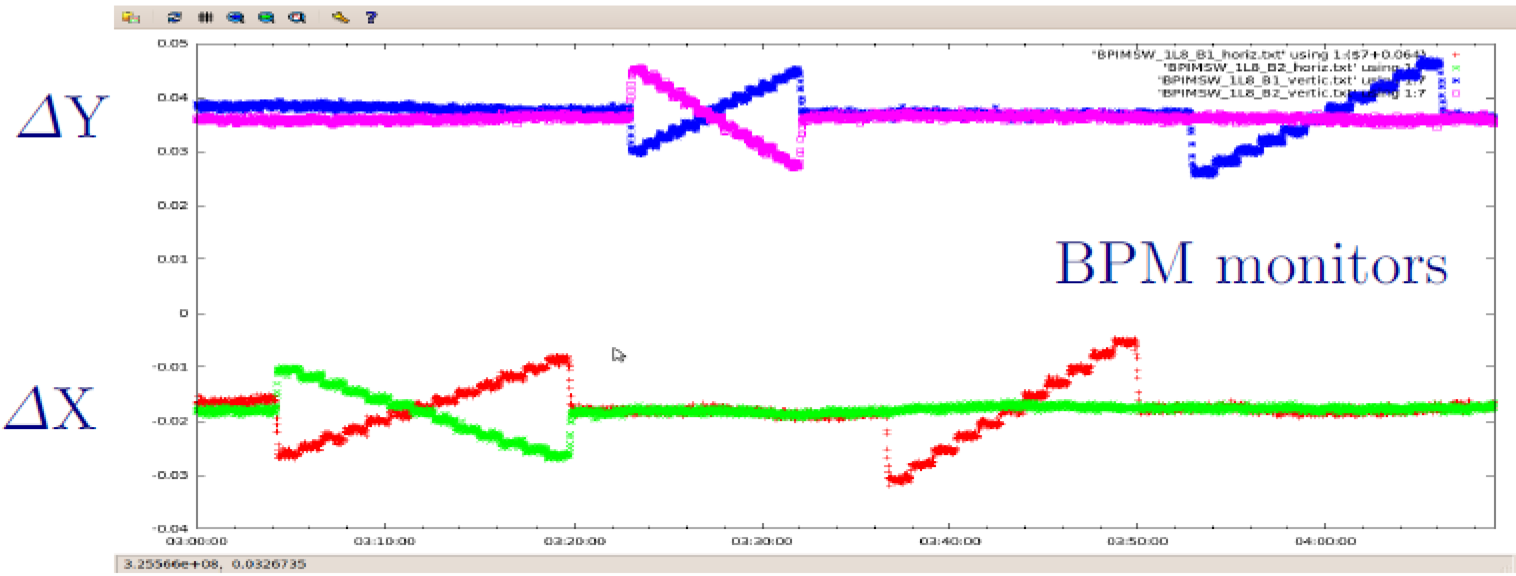
- 13 bunches per beam
- Each about 2.5e10 p/bch
- 8 colliding pairs per IP
- Single bunch effects visible ?
- More data from the experiments awaited:
  - Combine data from all 4 IP's which have different pairing of bunches
  - Luminous region parameters (x,y,z positions and sizes)





Van der Meer scans

Vladislav Balagura, CERN & ITEP,
LPC & LBS, 17 May 2010

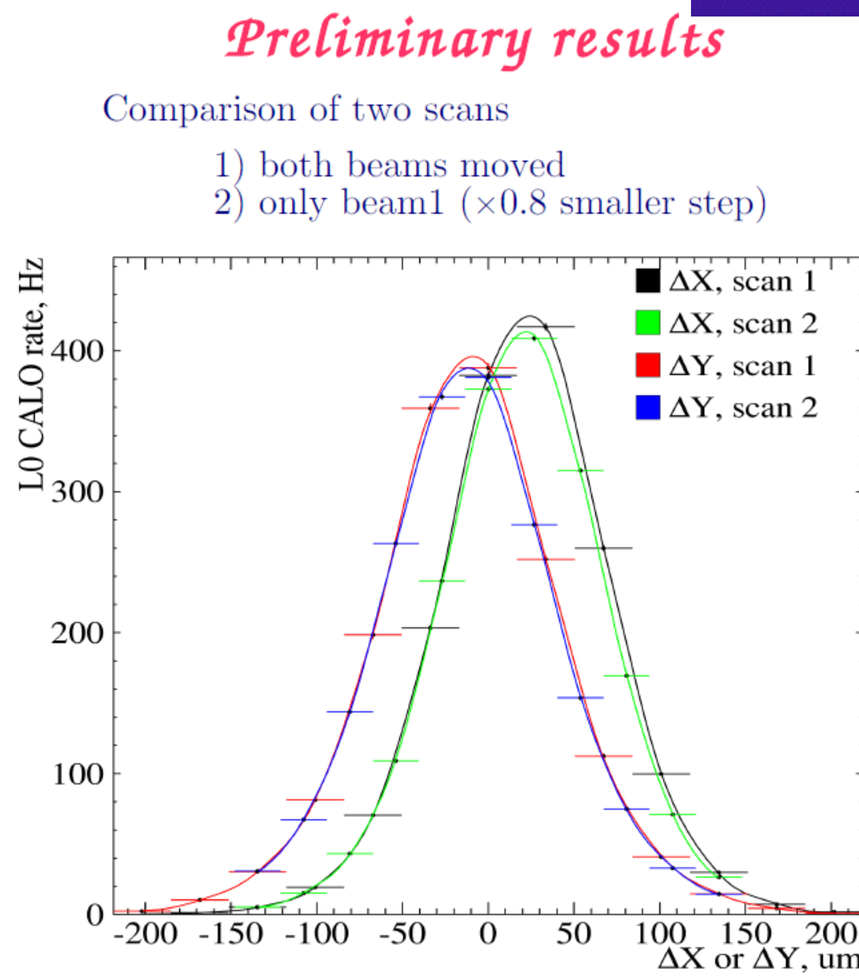


both beams moved symmetrically

only beam1
(to see movement of luminous region in VELO ⇒ scale)

Van der Meer scans

- Scans done at all IPs
  - 2xIP1
  - 2xIP5
  - 1xIP8
  - 1xIP2
- Profit from modest bunch charge (small beam-beam effects)
- First attempts expected to give ~10% uncertainty on absolute luminosity determination
- Uncertainty dominated by knowledge of individual bunch populations



Beam-gas imaging and luminosity

See NIM A553 (2005) 388

- A novel method to measure absolute luminosity of colliding beams (here beam1 and beam2)

- Assume $v_1 = v_2 = c$ and crossing angle ϕ

$$L = f \underline{\underline{N_1 N_2}} \, 2c \cos^2(\underline{\underline{\phi}}/2) \int_{4-\mathrm{fold}} \underline{\underline{\rho_1(\mathbf{x},t)}} \, \underline{\underline{\rho_2(\mathbf{x},t)}} \, d^3x \, dt$$

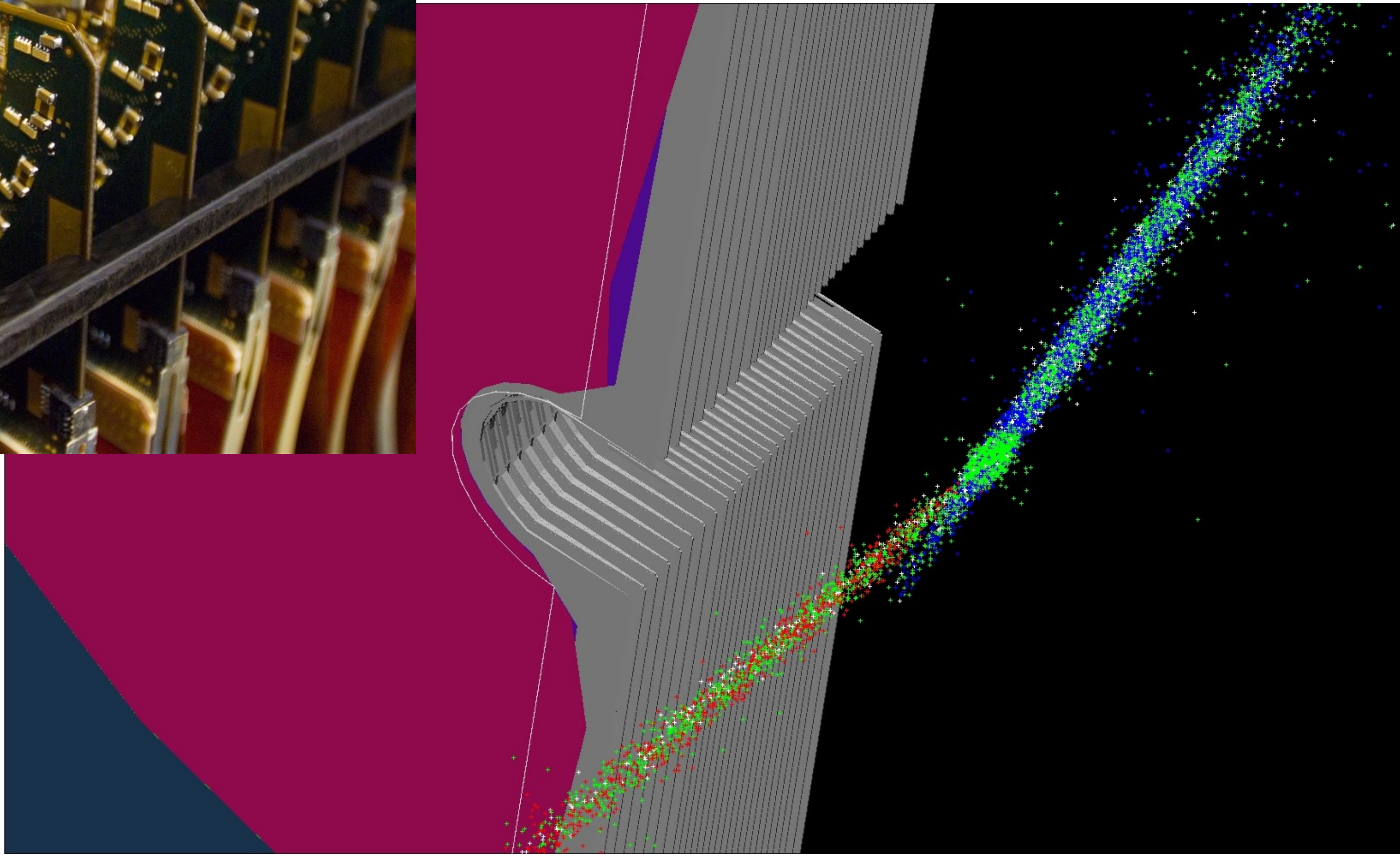
Measured by beam instrumentation

Measured by vertex reconstruction of beam-gas interaction

- Sampling the beam profiles with the residual gas…

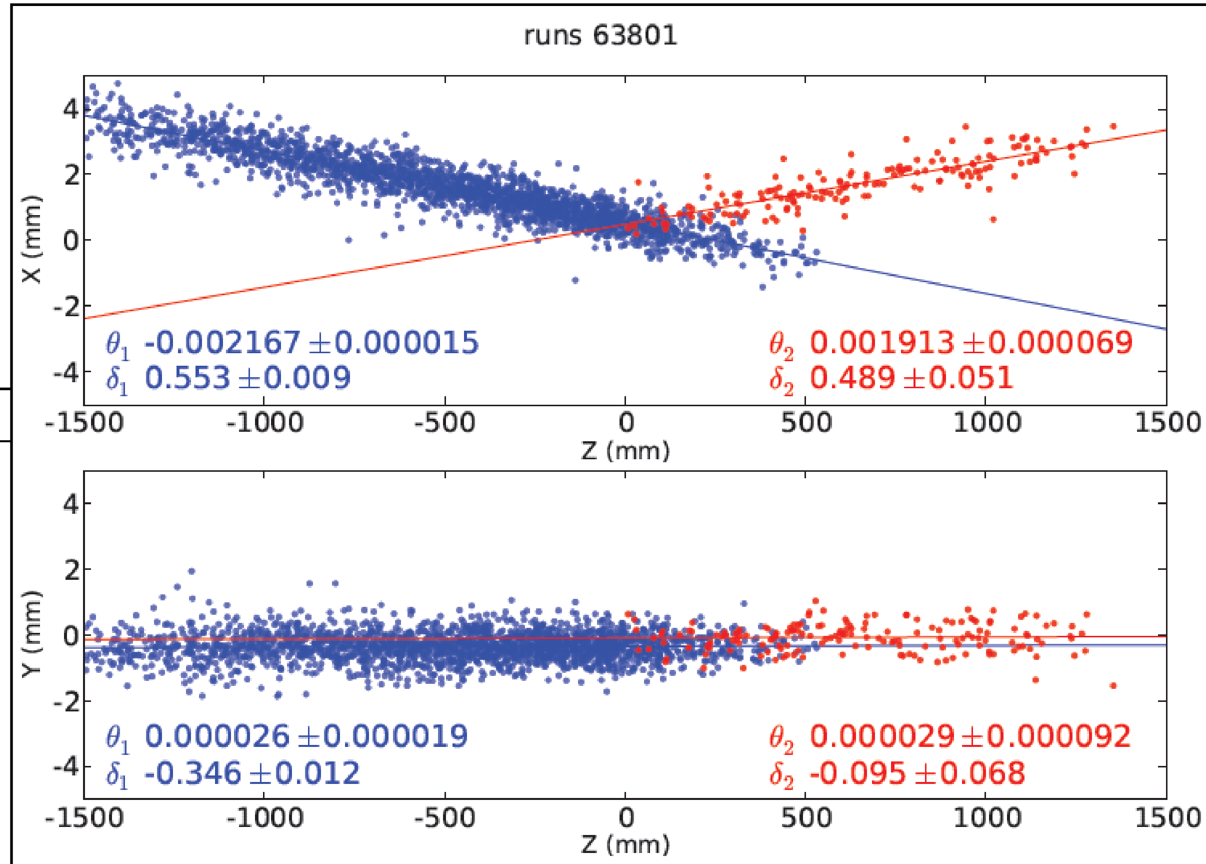
The LHCb VELO as a beam imaging device

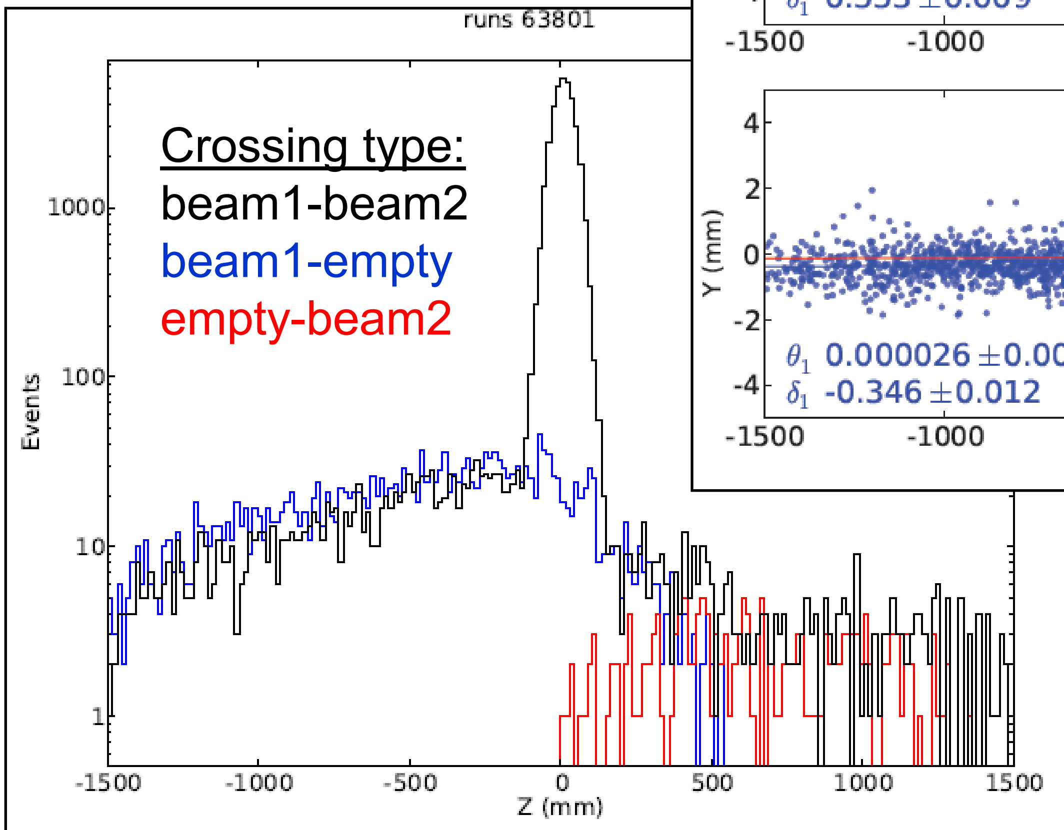
- At 450 GeV the VELO is not fully closed around the beam (for safety reasons)
- Still, can reconstruct the beams!



Example, 450 GeV beam imaging (2009)

Angle from dipole spectrometer bump



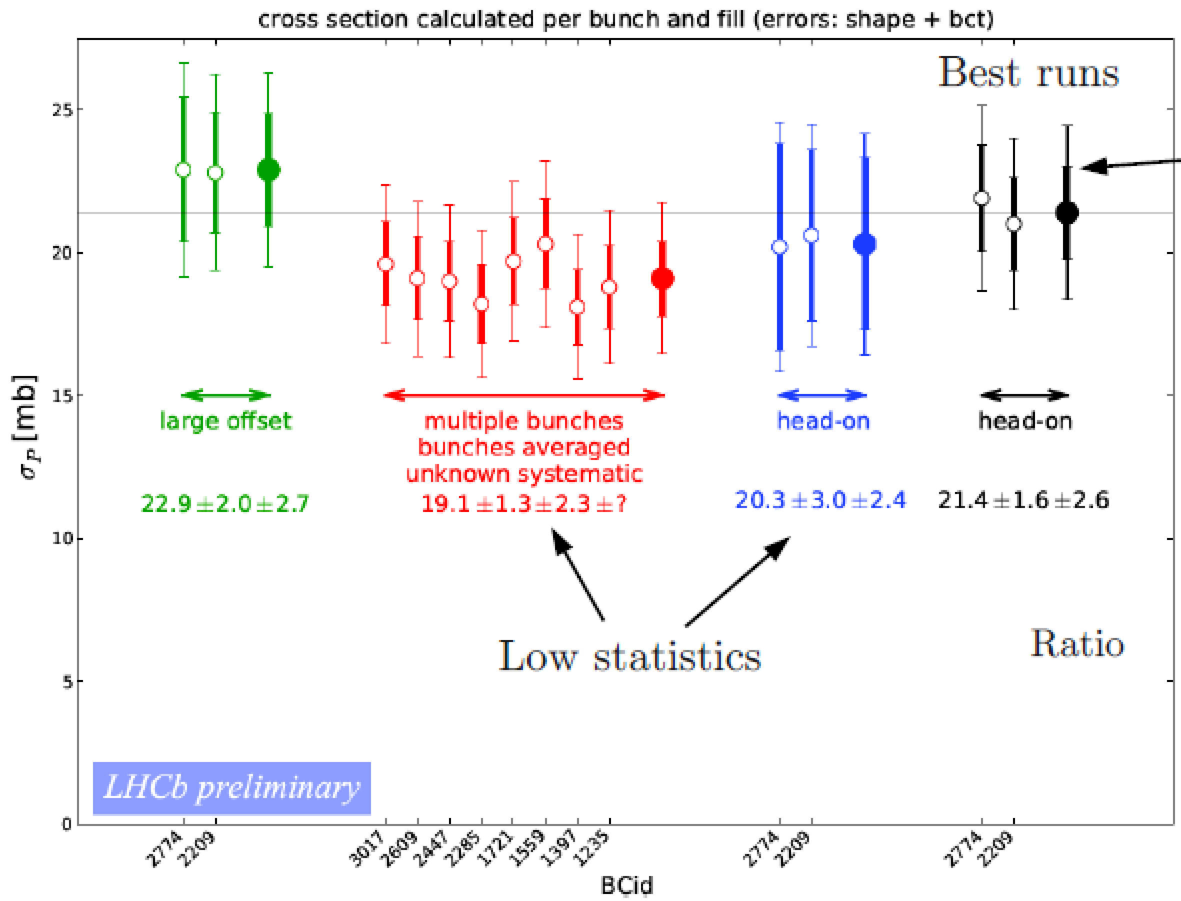


And the VELO was not even closed around the beams…

Prelim results for 900 GeV (<1 nb^{-1} and VELO open !!)

Time stability

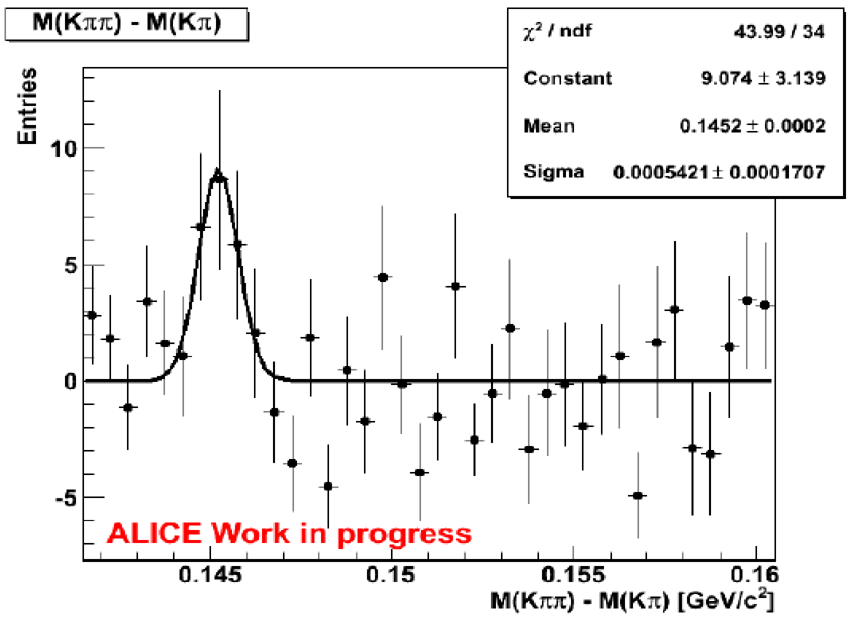
"Visible" cross section (after trigger and recon. eff.):
before beam alignment, with 16+1 bunches, two LHC fills with alignment

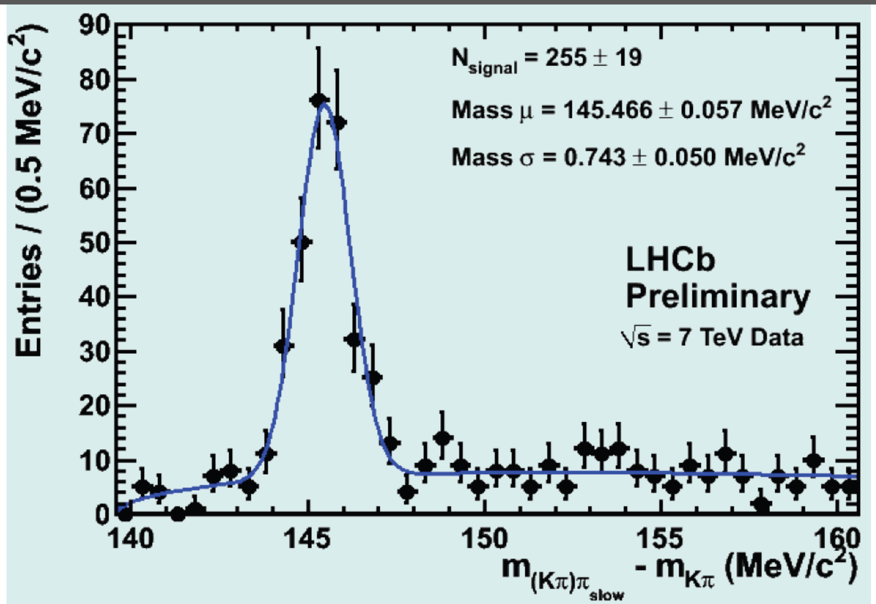


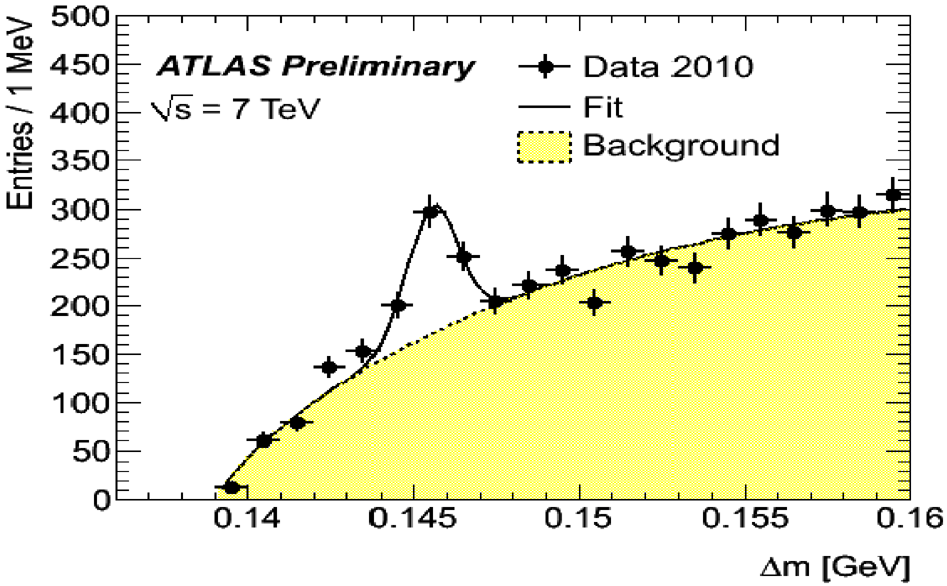
Without uncertainty in beam intensities

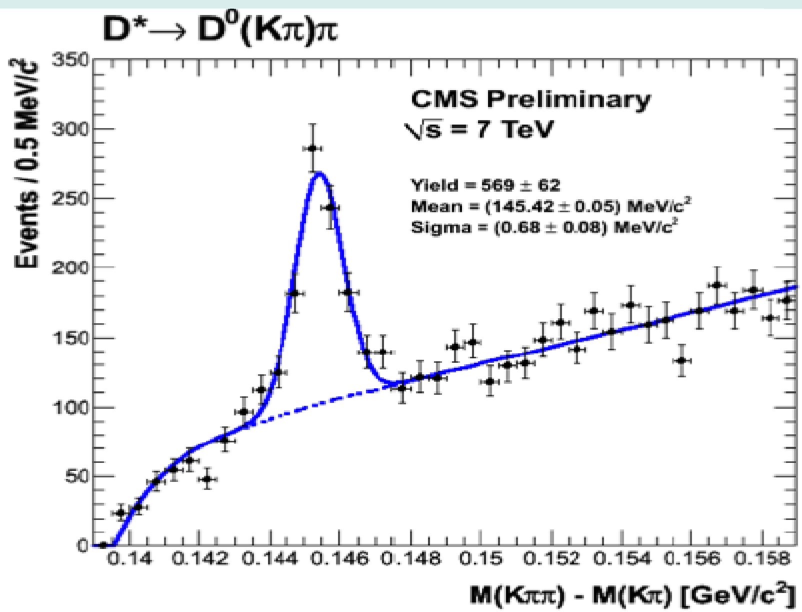
Vladislav Balagura, CERN & ITEP
on behalf of LHCb,
Moriond, 14 Mar 2010

The Charm Era of the LHC (D* → Dπ)

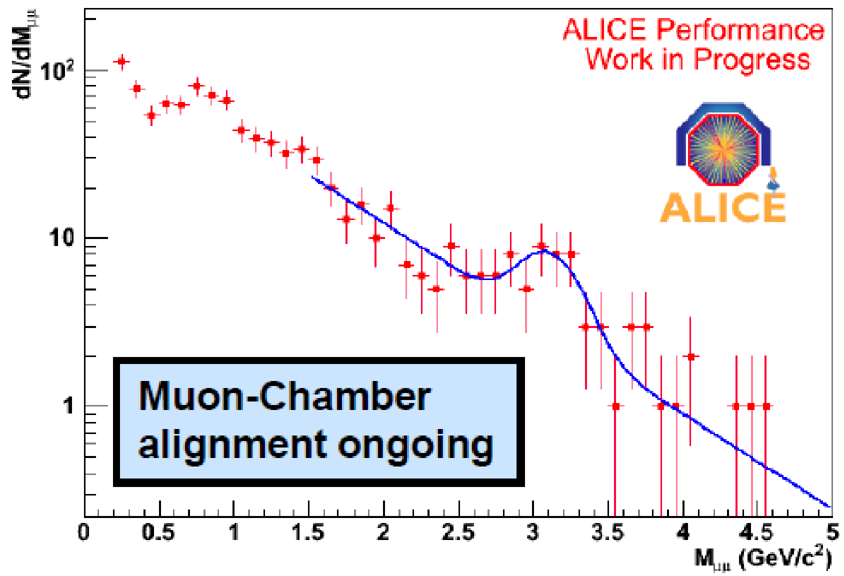


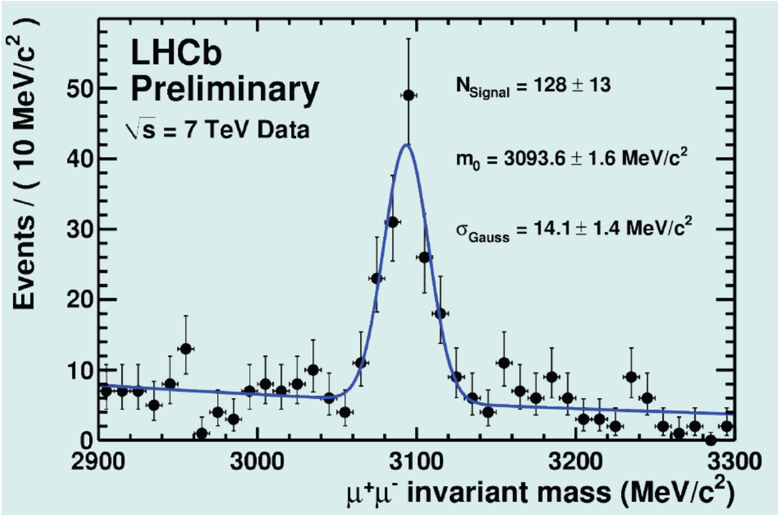


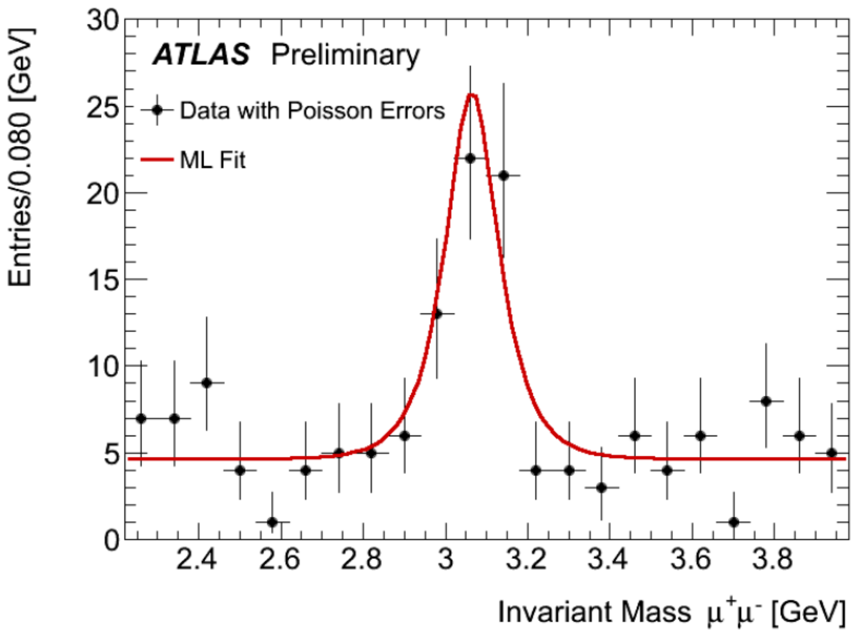


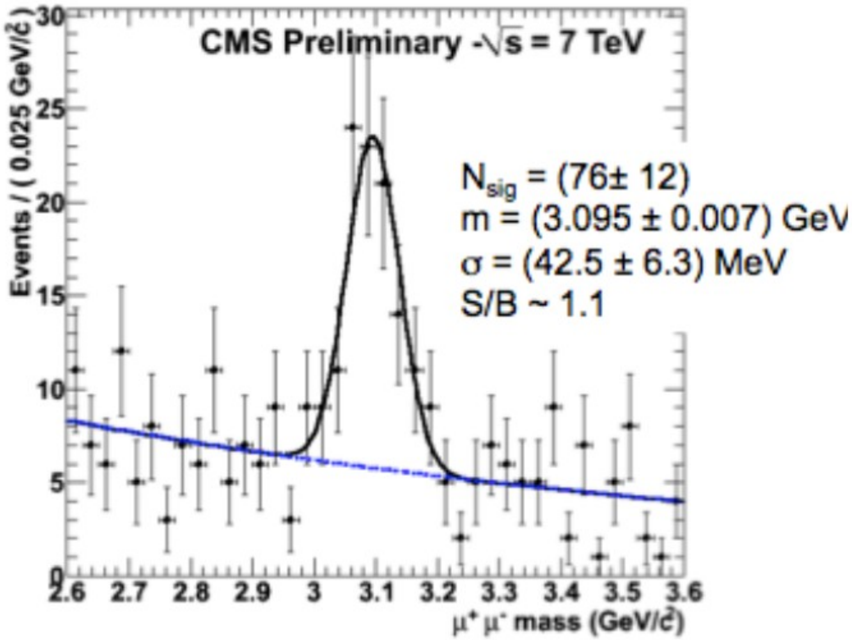


More Charm J/ψ→μμ (as seen by the LHC Programme Coordinator)



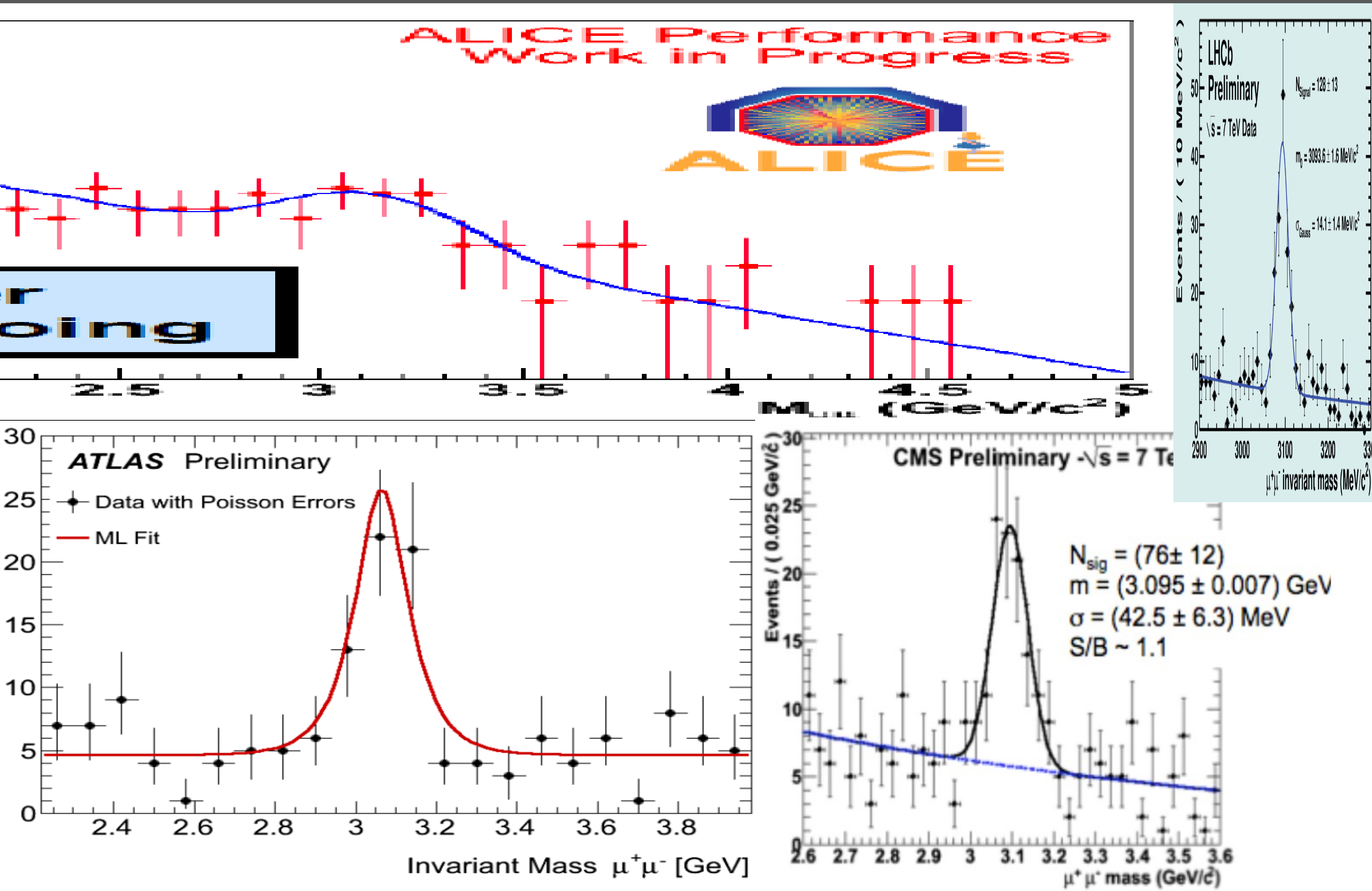




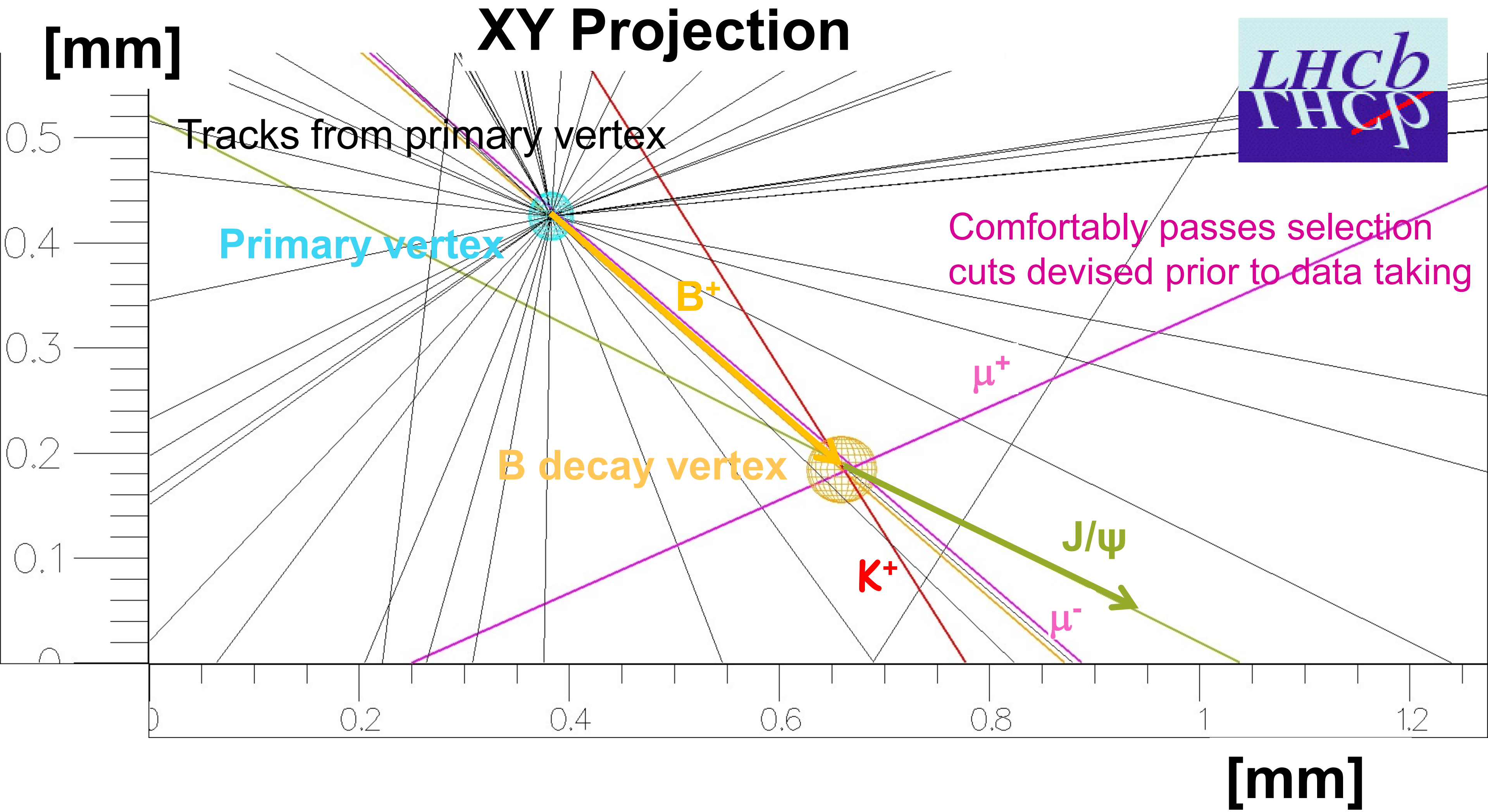


More Charm: J/ψ→μ μ

(as seen by an LHCb collaborator :)



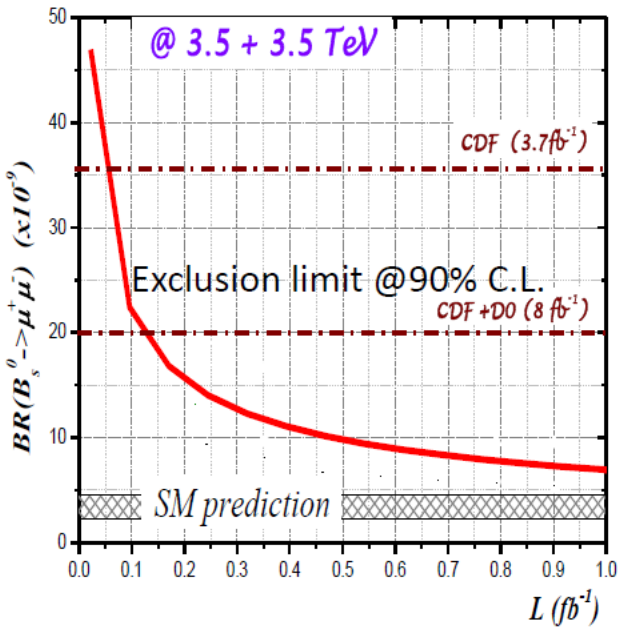
$B^+ \to J/\psi K^+$ candidate

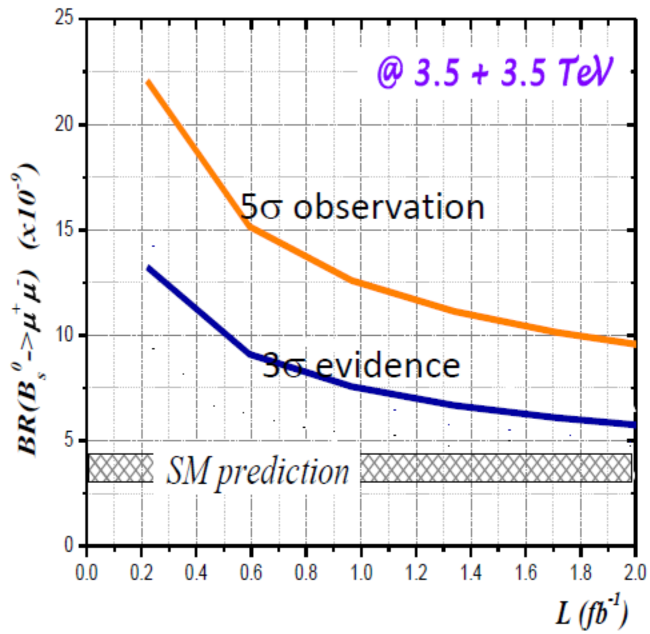


Prospects

LHCb prospects for $B_s \to \mu\mu$

All studies with existing data indicate that $B_s \to \mu\mu$ sensitivity as determined from simulation is realistic. The simulation studies give the following expectations:





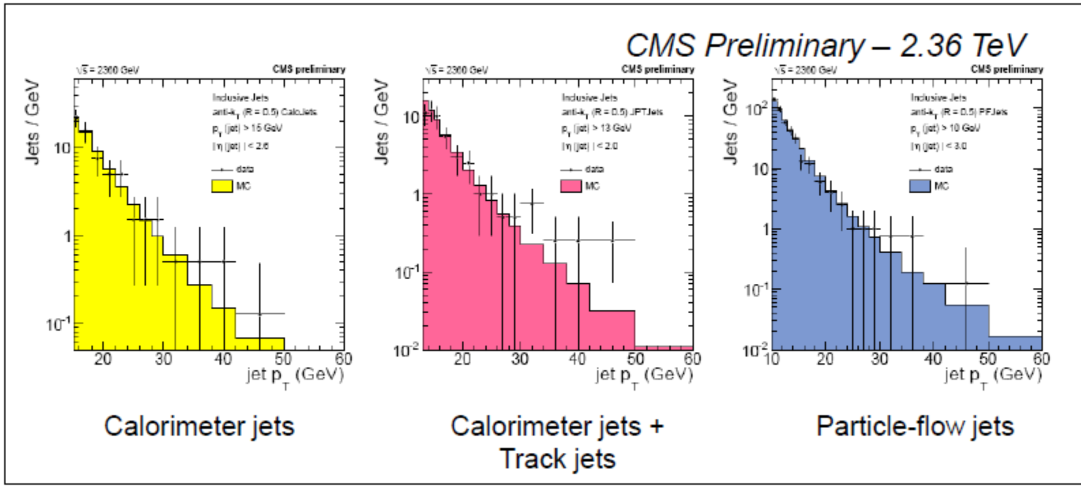
Already much is possible with 0.1 fb^{-1}; possibilities with 1 fb^{-1} are very exciting

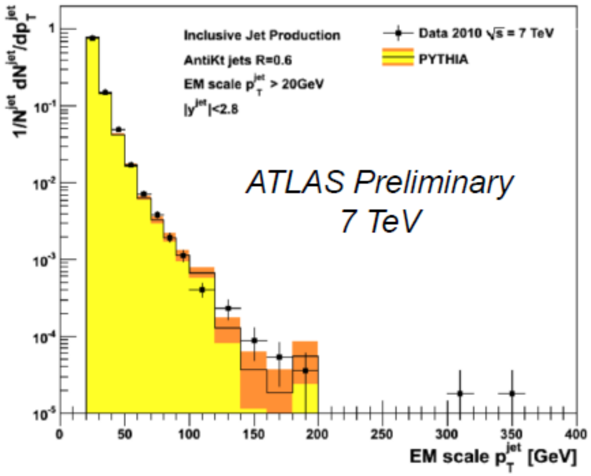
5/5/10 Heavy Flavour Prospects in the 2010-11 Run
Guy Wilkinson, LHCC 23

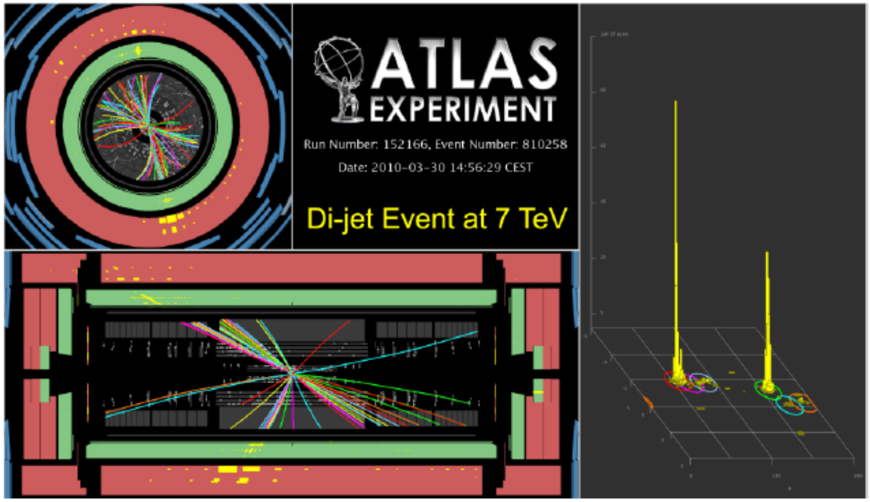
Jets

Jets Today

Both experiments see jets, and are busy producing a jet energy scale for the summer conferences.



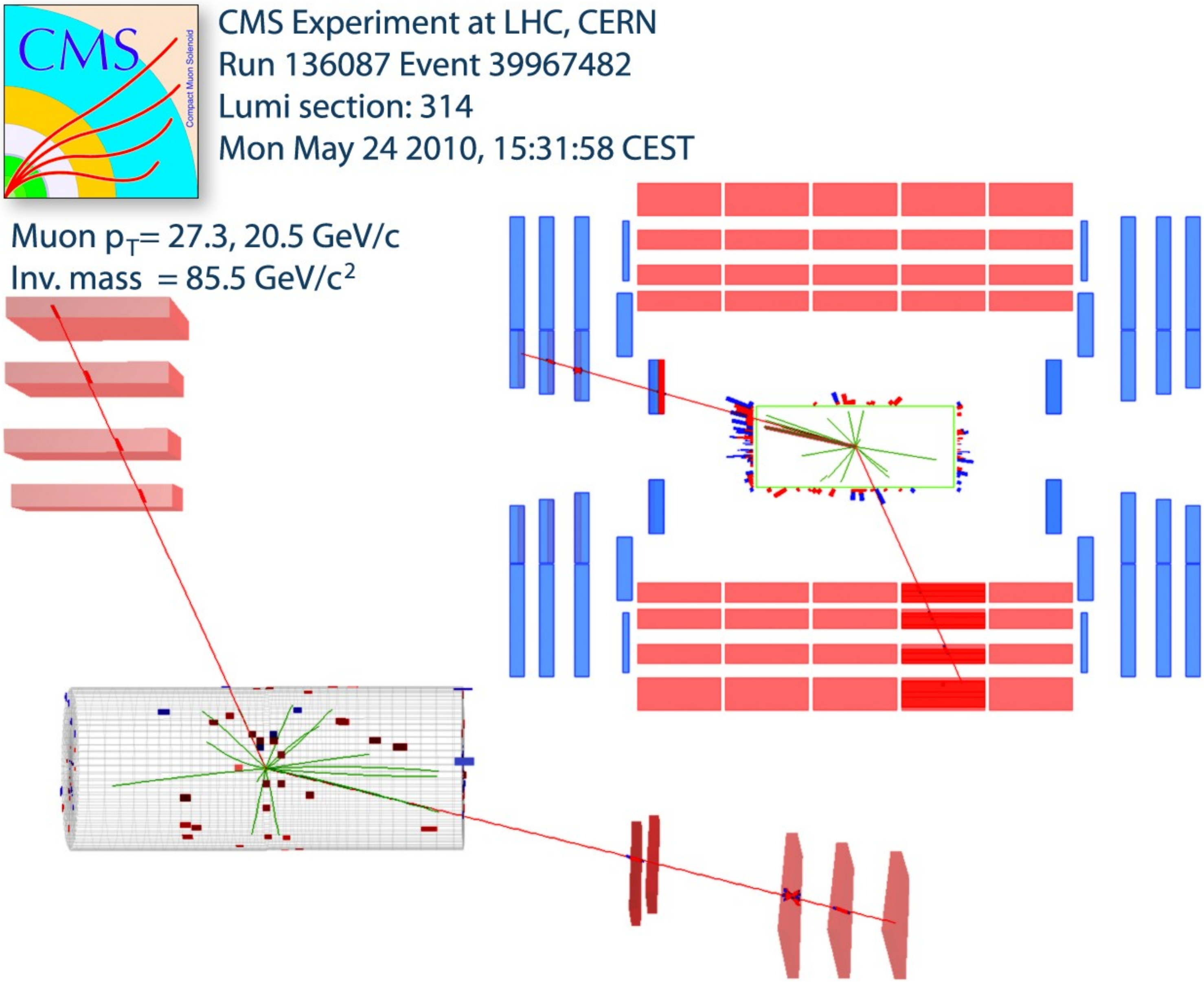




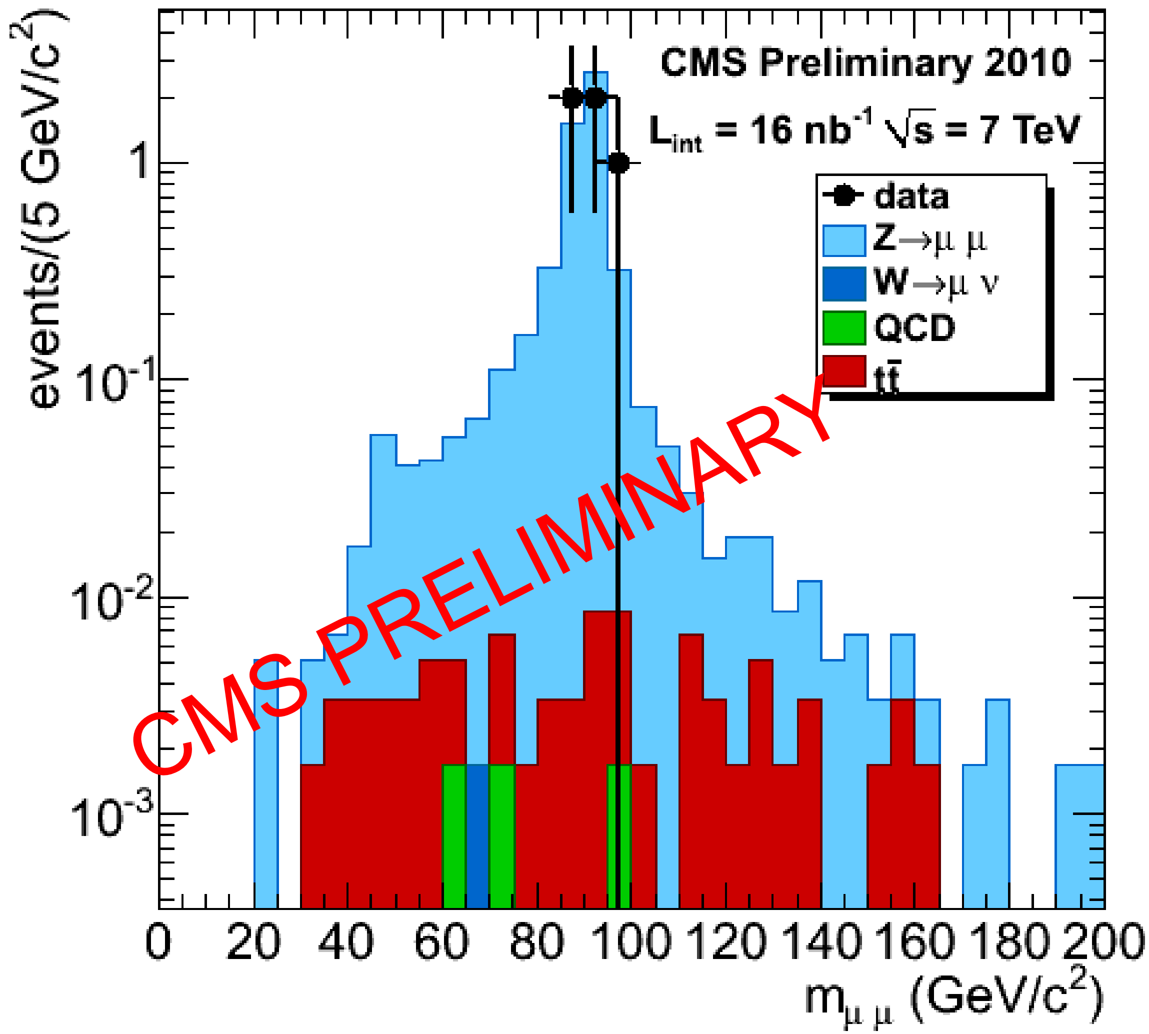
5

Tom LeCompte, ANL

Z→μμ candidate (Courtesy of CMS)



Z➔μμ Invariant Mass Distribution



Gaining a Factor 10 (or more)

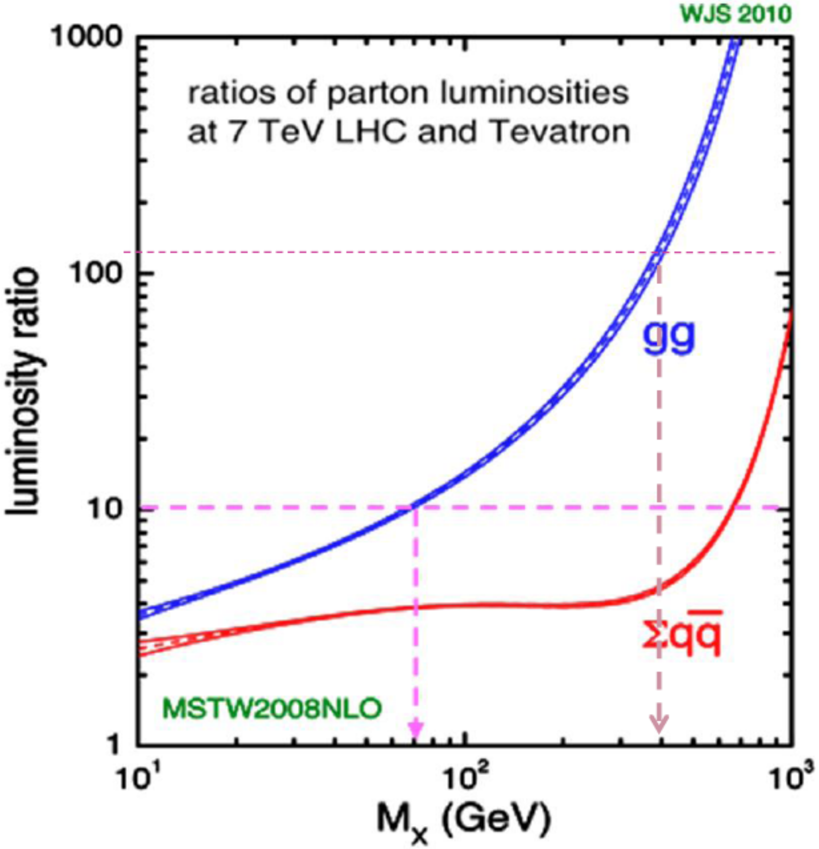
Use parton luminosties to illustrate the gain:

Example: mainly gg
Higgs: pp → H, H→WW and ZZ
Factor ~15

Example: gg and qq
Top: (85% qq, 15% gg at Tevatron)
Factor: 0.85 x 5 + 0.15 x 100
→ ~ 20

Squarks: ~350 GeV (assume top):
Factor: 0.85 x 10 + 0.15 x 1000
→ ~ 150 to 200

Z': ~1 TeV (qq)
Factor: ~ 50 to 100



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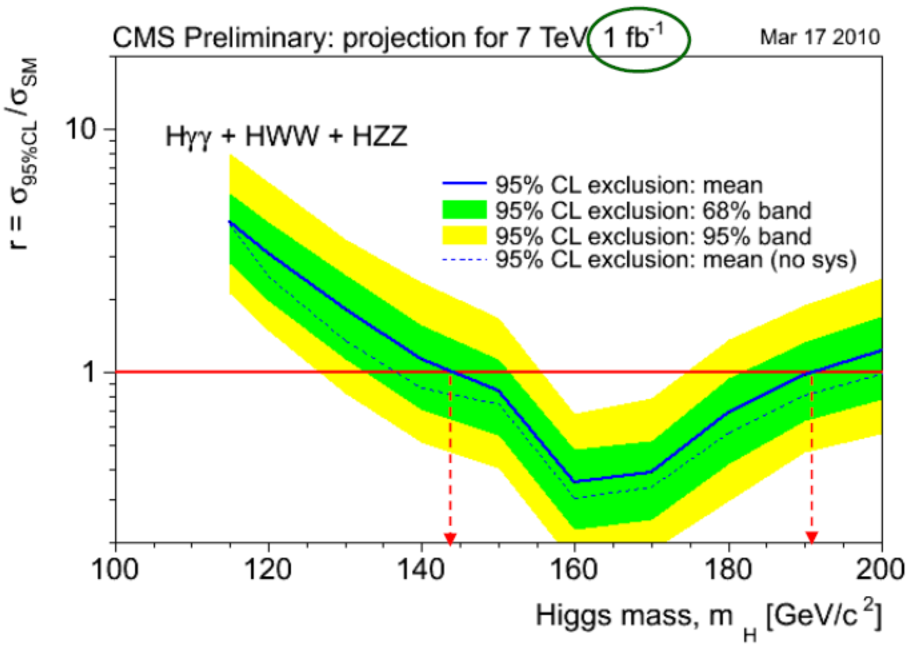
Standard Model Higgs: One Experiment

1 fb^{-1}

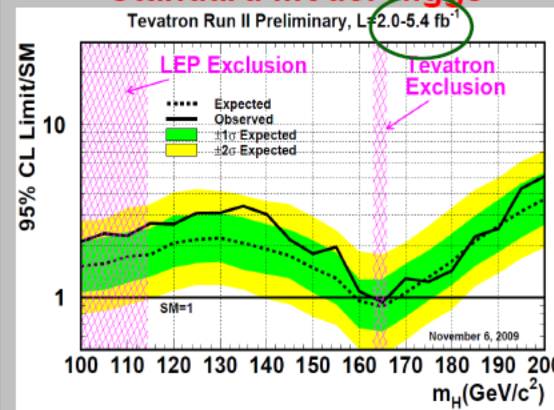
Exclusion: One experiment only



SM Higgs expected excluded range approx: **145-190 GeV**
3 to 5 Sigma at: ~**160 GeV**

TEVATRON CDF+D0

Standard Model Higgs



Tevatron 95% exclusion today: [162 to 166] GeV

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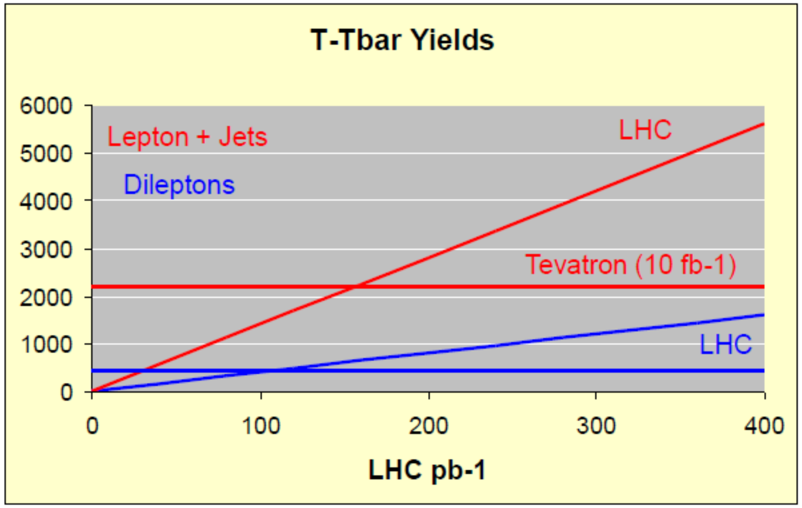
Top-antitop prospects

The Next Few Hundred pb^{-1}

- Each experiment expects top yields of
  - Dilepton: ~400 per 100 pb^{-1}
  - Lepton (e & μ) + Jets: ~1400 per 100 pb^{-1} (with large variations depending on selection requirements)
- By the end of 2010, the LHC will have samples comparable to the Tevatron's.



- By the end of 2011, the top samples will be substantially larger
- The physics program with a few hundred pb^{-1} will look very familiar
  - Top cross-section (at a new energy)
  - Top mass (at the end of the year you will see averages over 4 experiments, not 2)
  - Single Top
  - Rare decays

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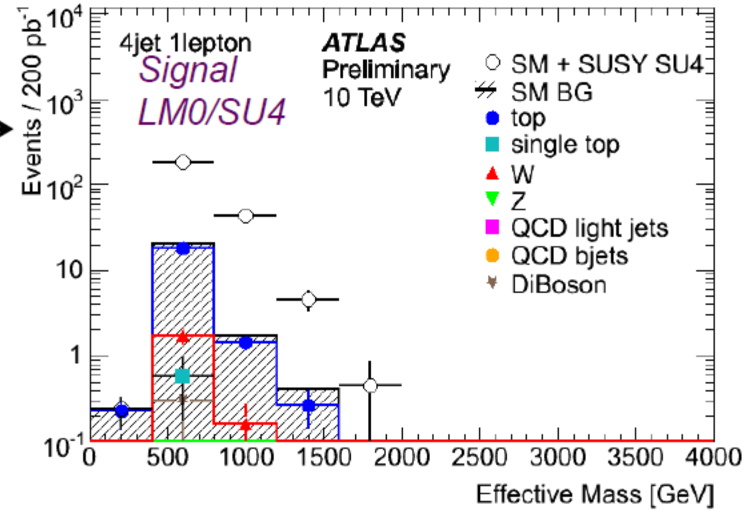
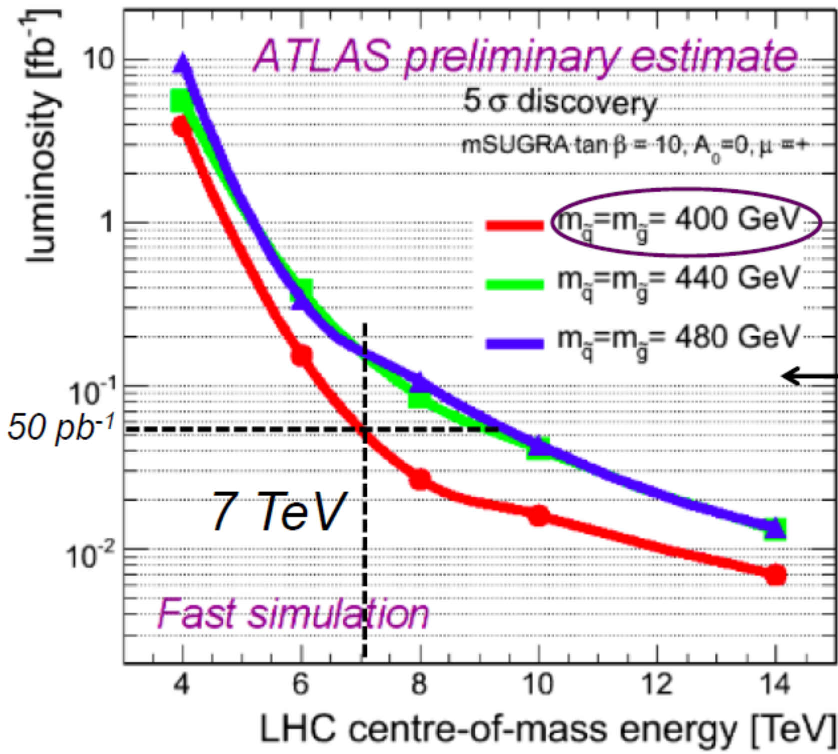
Jets+1 Lepton+E_T^{miss} Signature

Example: 200 pb^{-1} @10 TeV
(~ 700 pb^{-1} @ 7 TeV)





- *Exact reach depends strongly on assumed systematic – here 100%*
- *Discovery sensitivity beyond Tevatron from 50 pb^{-1} onwards.*
- *Channels combined discovery up to squark masses of ~750 GeV with 1 fb^{-1}*

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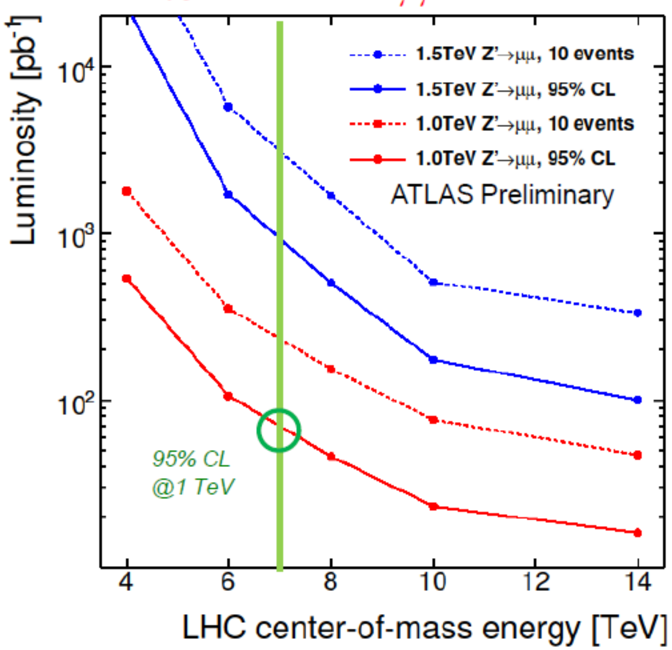
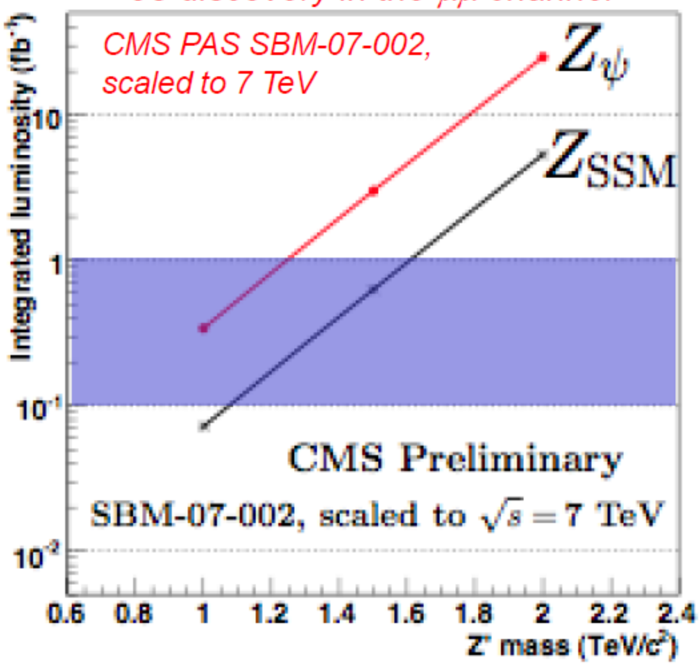
Dilepton Resonances (Example Z')

- Predicted in many SM extensions (Extra Dimensions, Technicolour, Little Higgs)
- Low, well understood background dominated by DY
- 95% CL exclusion O(100/pb) at 1 TeV
- Sensitivity beyond the Tevatron (1 TeV SSM Z') with ~100 pb^{-1}

95% exclusion in $\mu\mu$



5σ discovery in the $\mu\mu$ channel



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Outlook

- **The Target**: deliver 1 fb^{-1} at 3.5 TeV before the next long shutdown (~end of 2011)

- If assuming
  - Machine availability ~ 60 %
  - Physics time ~ 70%
  - Luminosity decay factor ~ 50%

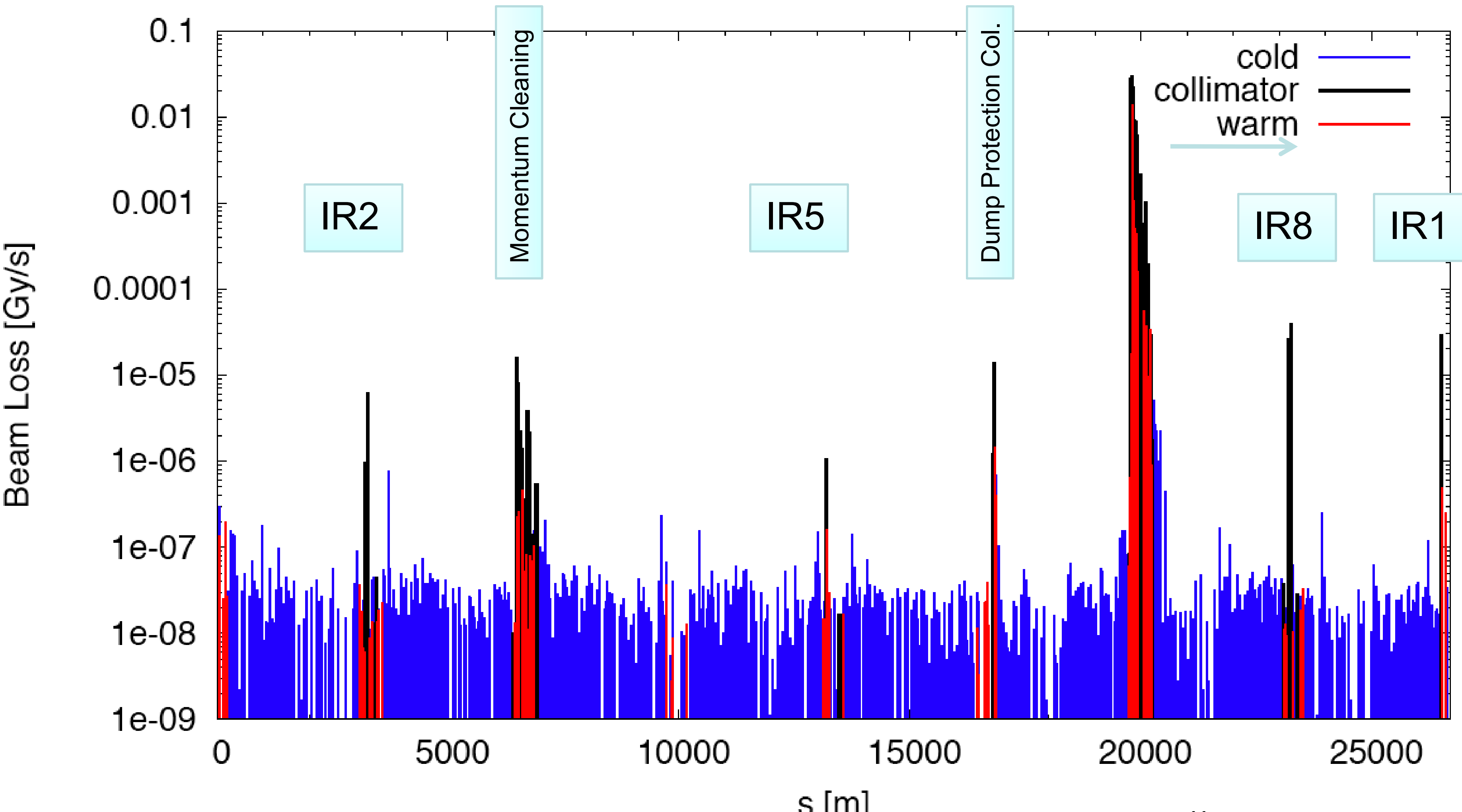
=> Need to operate LHC for ~9 months at L_{peak} ~2 x 10^{32} Hz/cm^2

- Still a long way to go!

- The pace of increase in intensity and luminosity will be driven by "safe and clean operation"

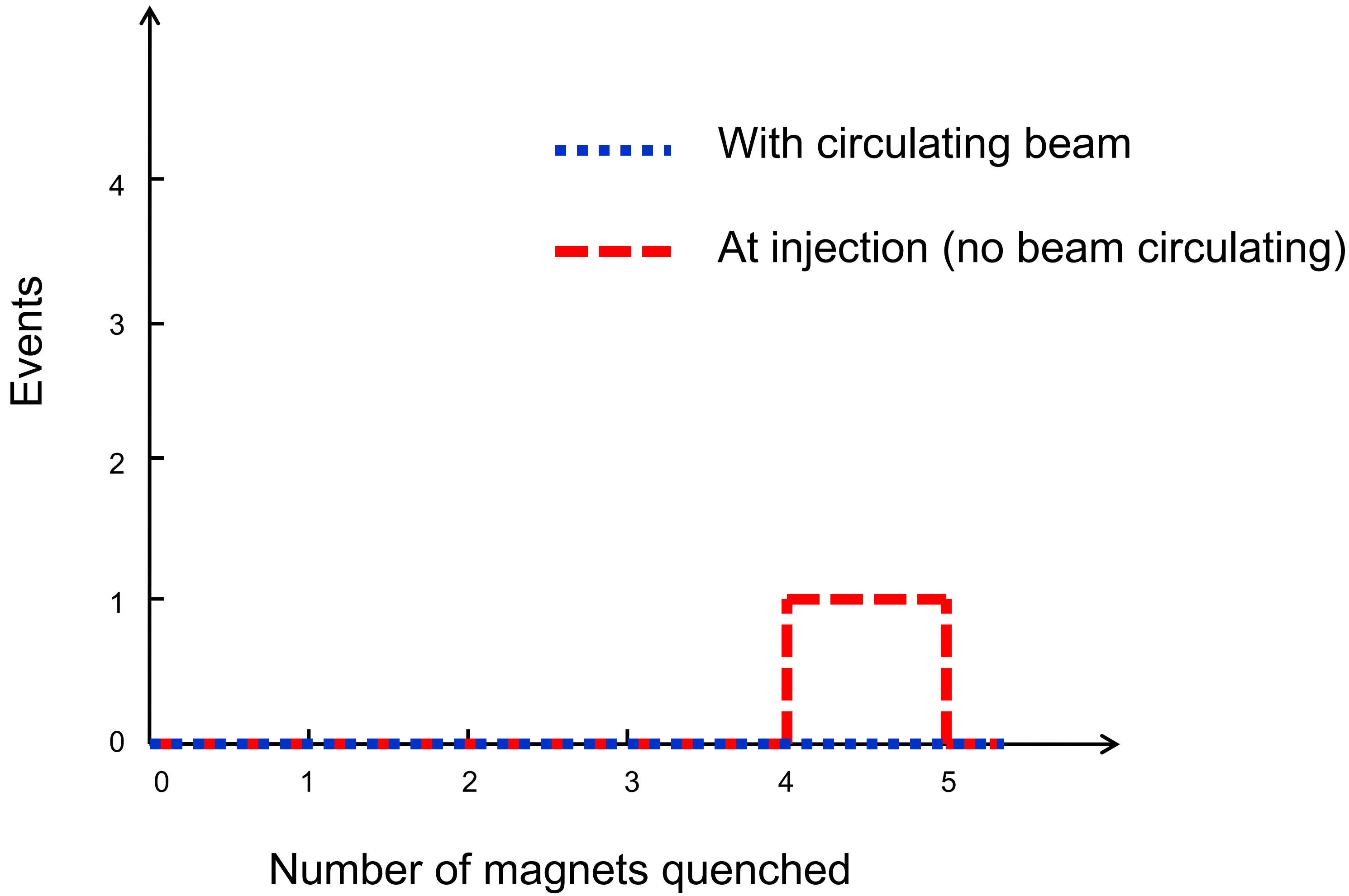
Cleaning/collimation

2m optics exposes IR's as expected! Protected by tertiary collimators.



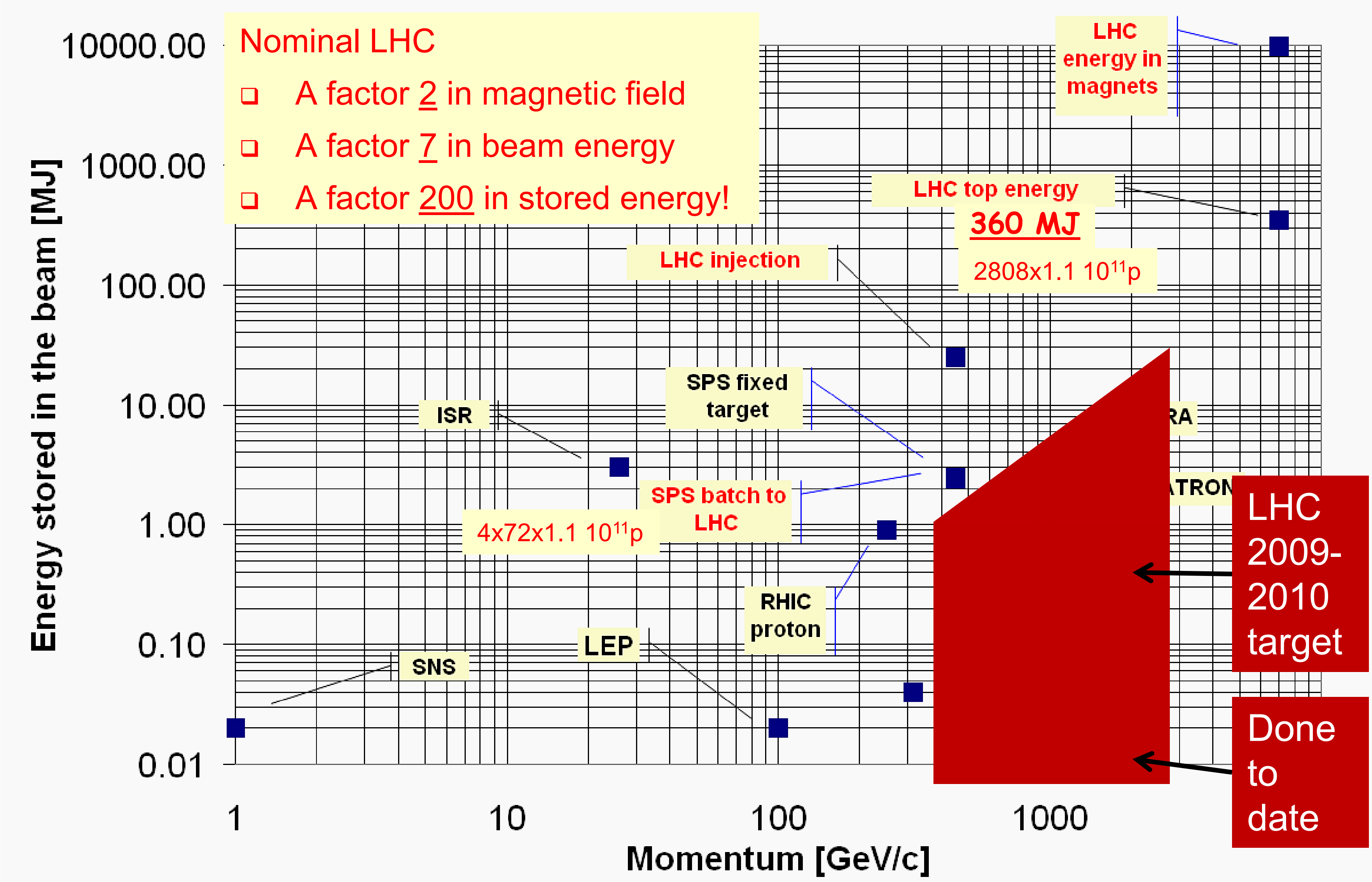
Collimation Team

So far, SC magnet quenches due to beam



LHC stored energy

- Despite modest luminosity (2e29 Hz/cm^2) we are at 0.18 MJ



Immediate future (conclusion)

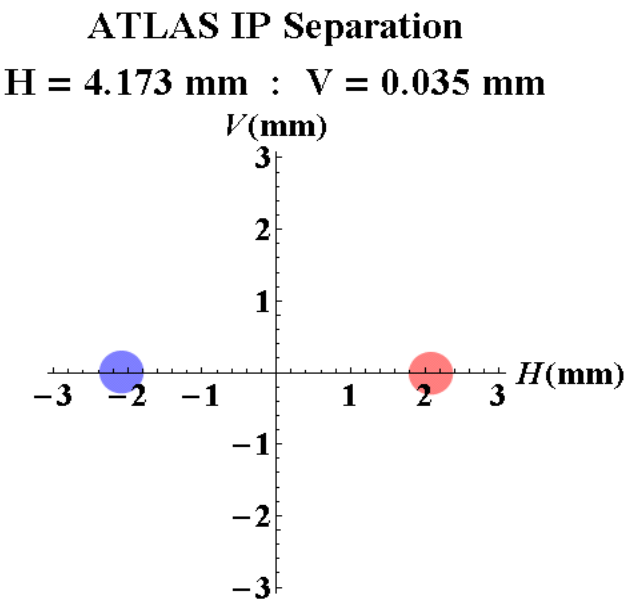
- Used successfully nominal bunches (1.1e11 p/bch) at 450 GeV/beam, in collision!
- Trying now 1.1e11 p/bch at 3.5 TeV/beam
  - Beam-beam effects should be worse at 450 GeV than at 3.5 TeV!
  - But taming these bunches is not so trivial…
- Decided to step back in beta star (to 5m) for a while
  - Allow more space for crossing angle and collimators/protection devices adjustments (less stringent tolerances)
- Increase number of bunches in steps
  - Need crossing angle as soon as ~200 bunches
  - Crossing angle also allows more flexibility in filling patterns
- After gained enough experience with high intensity beams (>1MJ), try to squeeze again to ~3m, or less.
- The aim is to reach $\sim 10^{32}$ Hz/cm^2 by end of 2010

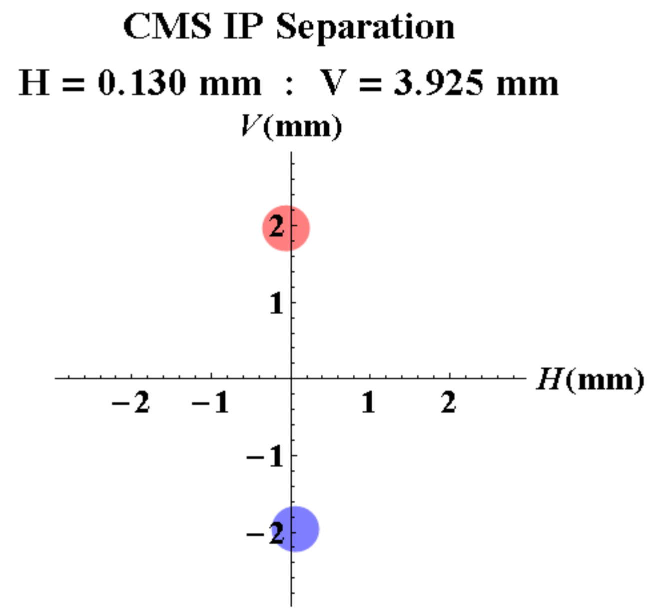
Commercial

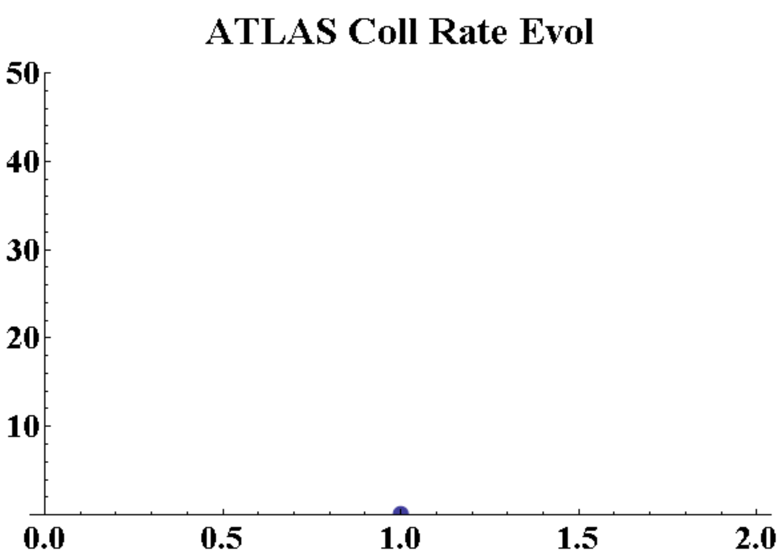
- Please, share the excitement with us!

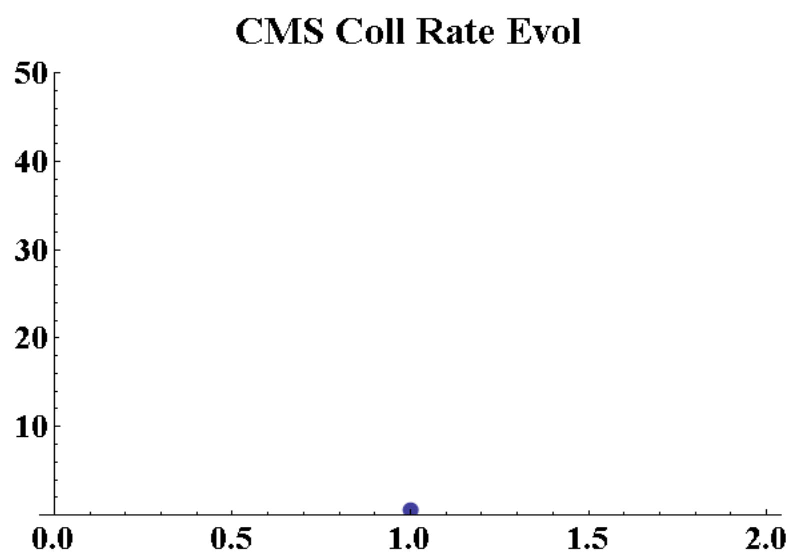
Backup slides

FIRST COLLISIONS AT 3.5 TeV/beam

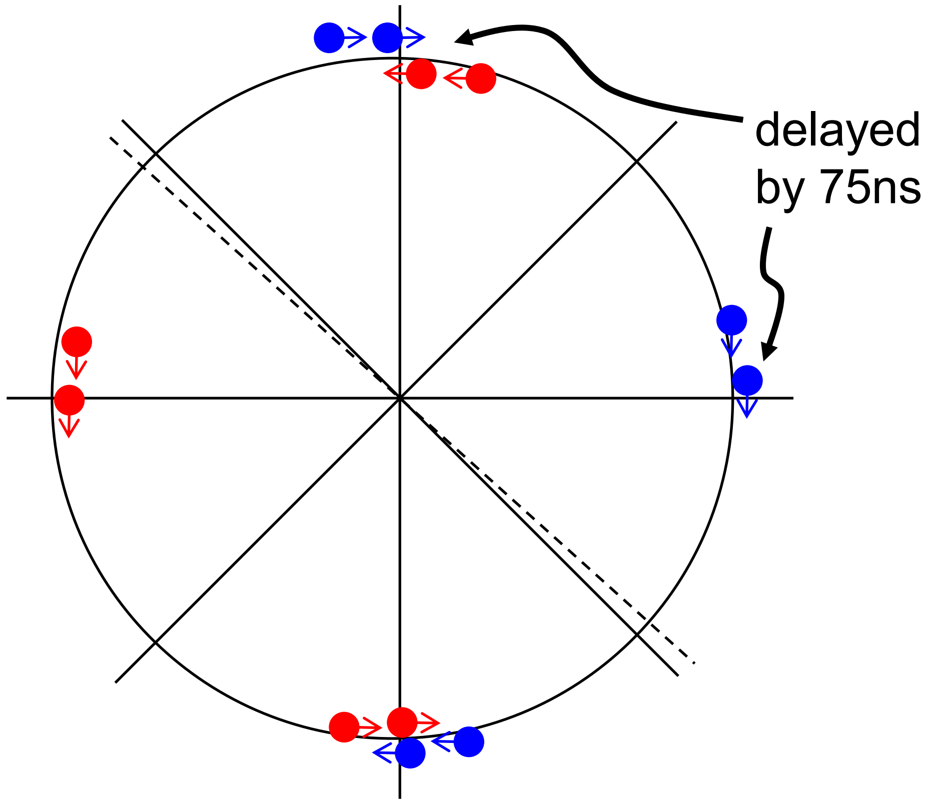








The 3x3 scheme (or the 2n/3 scheme)



- Two colliding pair in all IPs
- One non-colliding bunch per beam in all IP's (but parasitic in IP1 and IP5, unless small crossing angle)
- Can also be used with more bunches (n) => 2n/3 colliding pairs

First squeezed stable beams

24-Apr-2010 05:32:51 Fill #: 1058 Energy: 3500.3 GeV I(B1): 3.28e+10 I(B2): 3.25e+10

	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	PHYSICS	PHYSICS	PHYSICS
Instantaneous Luminosity	1.284e-02	1.147e-02	1.444e-02	1.497e-02
BRAN Count Rate	1.966e+02	1.159e+02	3.518e+02	3.810e+02
BKGD 1	0.048	0.014	0.040	0.141
BKGD 2	5.000	24.770	5.608	2.321
BKGD 3	0.000	0.005	0.003	0.045

LHCf PHYSICS Count(Hz): 5.400 | LHCb VELO Position IN Gap: 0.0 mm | TOTEM: STANDBY

NB: the inst lumi numbers are used by EiCs to define if and in which order a lumi optimisation is needed

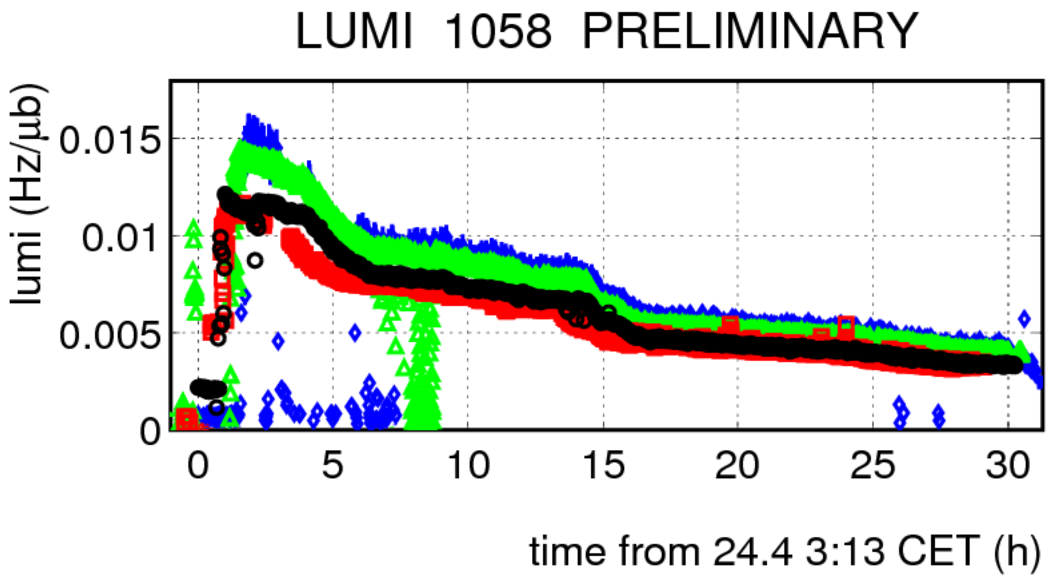
⇒ Important to have reliable (cross-expt comparable) numbers

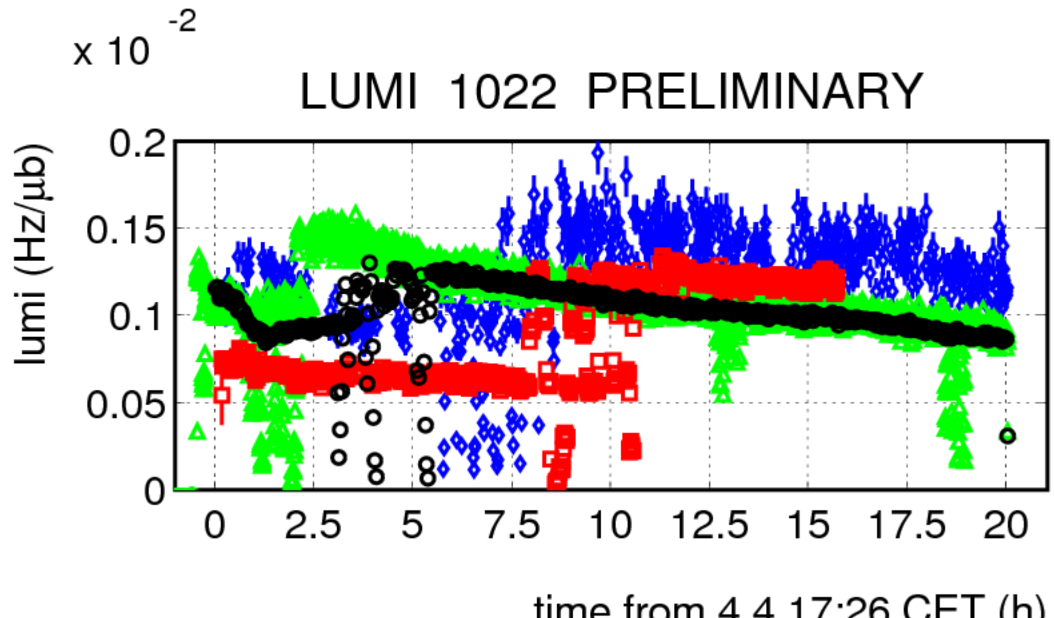
⇒ Inst lumi measurement available all the time (not only in stable beams)

Fill 1058

- First physics fill with b* = 2m in all IPs
- 3 bunches on 3 bunches (2 collisions per IP)

IP1	(ATLAS)
IP2	(ALICE)
IP5	(CMS)
IP8	(LHCb)



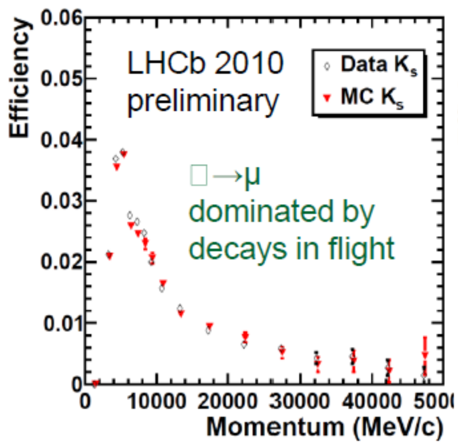


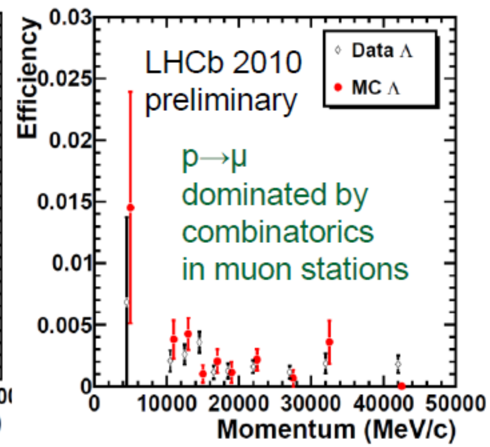
LHCb preparing for $B_s \to \mu\mu$

Muon identification studies

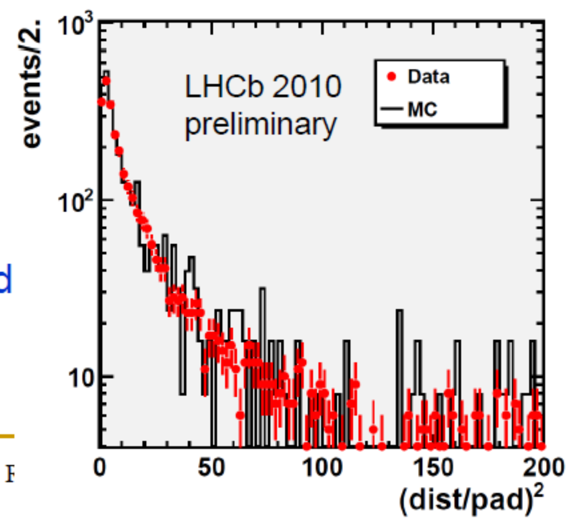
$B_s \to \mu\mu$ sensitivity relies on good performance of muon-identification. Misid performance is already under study. (Muon efficiency will be measured with J/ψ's)

Fake rate data and simulation for *first* stage of algorithm





Squared distance between background hits in muon system & extrapolated tracks



Next step will be to calibrate likelihood which is used to achieve higher suppression. First look at key ingredients shows promising data/MC agreement

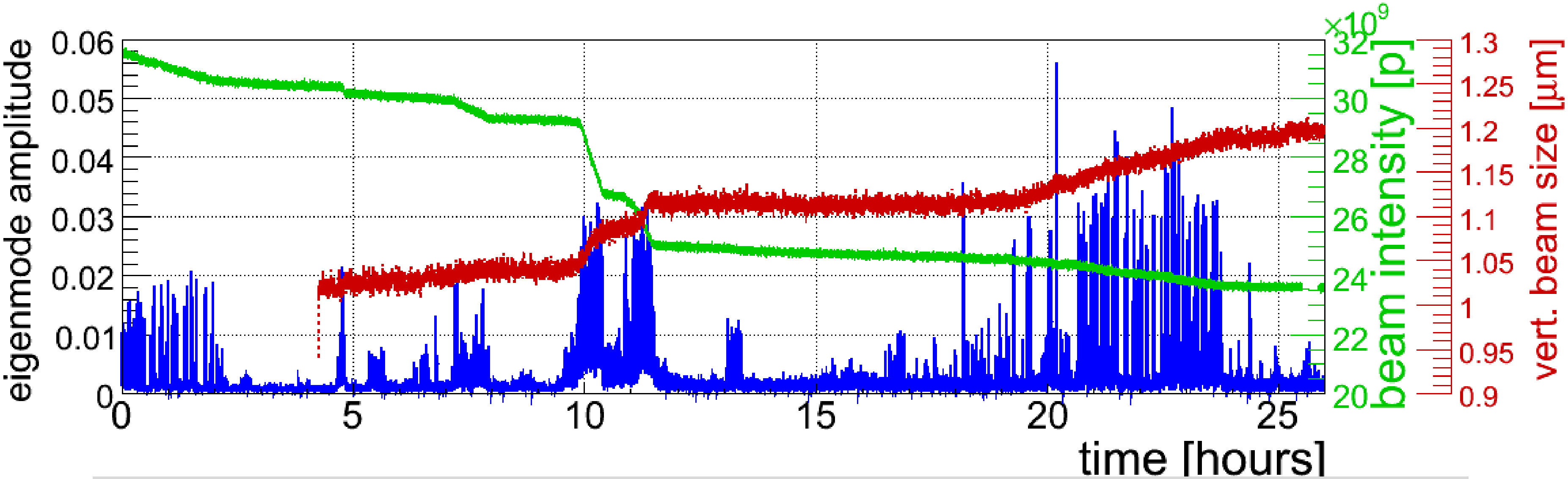
5/5/10

Heavy Flavour Prospects in the 2010-11 F
Guy Wilkinson, LHCC

Spurious noise exciting the beam

- Fast (but low amplitude nm to μm) oscillation of the beams.
- Sometimes it is present, sometimes it is not.
- Beam 2 is more affected…
- The frequency changes slowly (7-8 minute period), and when the frequency coincides with the tune it leads to emittance blow-up.

>> still hunting for the source….



currently, lumi life time (>10 h!!) dominated by transverse emittance growth